REVISION 1
PHASE 2 WORK PLAN
ADDENDUM FOR REMEDIAL INVESTIGATION/FEASIBILITY STUDY
Berry's Creek Study Area

Prepared for

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LIST OF ACRONYMS

ADCP	Acoustic Doppler Current Profiler
ADV	Acoustic Doppler Velocimeter
ANOVA	Analysis of Variance
ANPP	Aboveground Plant Biomass and Net Primary Production
AOC	Administrative Order of Consent
ARARs	Applicable or Relevant and Appropriate Requirements
ASM	Adaptive Site Management
BAZ	Biologically Active Zone
BCC	Berry's Creek Canal
BCSA	Berry's Creek Study Area
BCUA	Bergen County Utility Authority
BDOC	Biodegradable Organic Carbon
BERA	Baseline Ecological Risk Assessment
BHHRA	Baseline Human Health Risk Assessment
BMI	Benthic Microalgae
BSAWA	Bureau of Systems Analysis and Wasteload Allocation
Cd	Cadmium
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CLP	Contract Laboratory Program

cm	Centimeter
COC	Chemical of Concern
COPCs	Chemicals of Potential Concern
Cr	Chromium
Cs	Cesium
CSM	Conceptual Site Models
CSTAG	Contaminated Sediments Technical Assistance Group
CTM	Candidate Technologies Memorandum
CW	Carapace Width
DLC	Dioxin-like Congeners
DO	Dissolved Oxygen
DOC	Dissolved Organic Carbon
DMP	Data Management Plan
DMS	Database Management System
DQO	Data Quality Objectives
EEM	Excitation Emissions Matrices
ELM	Environmental Liability Management
EPCs	Exposure Point Concentrations
ERA	Ecological Risk Assessment
EVI	Enhanced Vegetative Index
FCU	Functional Capacity Units
FISP	Federal Interagency Sedimentation Program
FLSB	Wet Labs ECO Fluorometers
FS	Feasibility Study
FSP	Field Sampling Plan
ft	Foot
g	Grams
GC	Gas Chromatography
GCA	Gut Content Analysis
GIS	Geographical Information Systems
GRAs	General Response Actions
Hg	Mercury
HHRA	Human Health Risk Assessment
HRB	Hackensack River Background
IDW	Investigation Derived Waste
in	Inch
IRM	Interim Remedial Measure
lb	Pound
LADD	Lifetime Average Daily Dose
LBC	Lower Berry's Creek
LHR	Lower Hackensack River
LISST	Laser *In Situ* Scatter and Transmissometry
m	Meter
MBC	Middle Berry's Creek
MeHg	Methylmercury

MERI	Meadowlands Environmental Research Institute
MHHW	Mean Higher High Water
mm	millimeter
MNR	Monitored Natural Recovery
MS	Matrix Spike
MSD	Matrix Spike Duplicate
N	Nitrogen
NCP	National Contingency Plan
NDVI	Normalized Difference Vegetative Index
NJ	New Jersey
NJAC	New Jersey Administrative Code
NJADN	New Jersey Atmospheric Deposition Network
NJMC	New Jersey Meadowlands Commission
NJDEP	New Jersey Department of Environmental Protection
NJDOH	New Jersey Department of Health
NJSA	New Jersey Sports Authority
NJSEA	New Jersey Meadowlands Sports and Exposition Authority
NOAA	National Oceanic and Atmospheric Administration
NPP	Net Primary Productivity
OM	Organic Matter
ORP	Oxidation/Reduction Potential
PAHs	Polycyclic aromatic Hydrocarbons
PAR	Pathway Analysis Report
Pb	Lead
PCBs	Polychlorinated Biphenyls
PCDD	Polychlorinated Dibenzodioxins
PCDF	Polychlorinated Dibenzofurans
PIC	Peach Island Creek
POC	Particulate Organic Carbon
PRG	Preliminary Remediation Goal
PPR	Paterson Plank Road
PRP	Potentially Responsible Parties
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QC	Quality Control
RAGS	Risk Assessment Guidance for Superfund
RAO	Remedial Action Objectives
RCRA	Resource Conservation and Recovery Act
RI	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
RPD	Redox Potential Discontinuity
RPM	Remedial Project Manager
RUR	Regional Urban Reference
SAWP	Scoping Activities Work Plan
SABS	Suspended and Bedded Sediment

SDG	Sample Delivery Group
SDMP	Scientific Decision Management Point
SI	Stable Isotope Analysis
SLERA	Screening Level Ecological Risk Assessment
SMU	Sediment Management Units
SOP	Standard Operating Procedure
SOW	Statement of Work
SPI	Sediment Profile Imaging
SRB	Sulfate-Reducing Bacteria
SWQS	Surface Water Quality Standards
TA	TestAmerica
TAL	Target Analyte List
T_L	Total Length
TOC	Total Organic Carbon
TSS	Total Suspended Solids
UBC	Upper Berry's Creek
UFP	Uniform Federal Policy
UOP	Universal Oil Products
USACE	United States Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
WP	Work Plan
Zn	Zinc
µg/L	Micrograms Per Liter
µm	Micromols

Note: Tables and Figures may have additional acronyms and abbreviations.

SECTION 1

INTRODUCTION

1.1 Overview

The Berry's Creek Study Area Cooperating Potentially Responsible Parties (PRP) Group (hereafter referred to as "the Group") has entered into an Administrative Order of Consent (AOC) Index No. II-CERCLA-2008-2011 with the U.S. Environmental Protection Agency (USEPA) Region 2 to perform a Remedial Investigation/Feasibility Study (RI/FS) pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). The Berry's Creek Study Area (BCSA or Site) is located in the New Jersey Hackensack Meadowlands (Meadowlands) in Bergen County, New Jersey. The nature of the RI/FS is described in a Statement of Work (SOW) presented as Appendix B to the AOC. This Phase 2 Addendum to the RI/FS Work Plan has been prepared by the BCSA consultant team, consisting of Geosyntec Consultants and Integral Consulting Inc., in consultation with the Project Coordinator, Environmental Liability Management (ELM), and the BCSA Technical Committee comprised of senior technical representatives from many of the parties to the AOC. Revisions were made based on comments received from the USEPA in June 2010, consistent with the responses to comments provided to USEPA on July 27, 2010. The July 2010 version of this document included the following tasks that have been approved by USEPA and are currently being implemented by the field team:

Task 2 – Surface Water Investigation
- A: Routine Monitoring (twice annual monitoring only)
- B.02: Marsh Intertidal Pool Sampling

Task 3 – Sediment Investigation
- B: Supplementary BAZ Sediment Sampling
- C: Surface Sediment Correlation Sampling
- D: Marsh Sediment Sampling
- E: *Phragmites* Sampling

Task 4 – Ground Water/Surface Water Interflow
- A: Marsh Interflow Characterization
- B: Focused Study of Groundwater Discharge from Landfills

Task 5 – Biota Investigation and Human Activities
- A: COPC Residues in the BCSA Food Web
- B: Monitoring of Human Activity Patterns in the BCSA
- C: Fish Community Survey
- D: Food Web Study

E: Benthic Survey
F: Qualitative Survey of Marsh Invertebrate/Insect Community
G: Evaluation of BCSA Marsh Production, Functions, and Values

Task 6 – Reference Site Evaluation
A: Biota Sampling
B: Marsh Sediment Sampling
C: *Phragmites* Sampling
D: Fish Community Survey
E: Food Web Study
F: Benthic Survey
G: Survey of Marsh Invertebrate/Insect Community
H: Evaluation of Reference Site Marsh Productions, Functions and Values

Task 9 – Data Management/Data Validation/Field Audits

This Revised Final October 2010 version includes additional revisions primarily related to the hydrodynamics (Task 1), surface water (Task 2), sediment (Task 3), and air (Task 7) tasks following a work session with the USEPA on August 4, 2010.

1.2 Purpose and Objectives

The RI/FS takes into account:

- History and urban nature of the watershed.
- The chemicals of potential concern (COPCs) that are the focus of the RI/FS.
- The eleven USEPA risk management principles for contaminated sediments.
- An adaptive management approach that is best suited to address the range of site-specific conditions in the BCSA.

The BCSA Phase 1 Project Documents include:

- Work Plan (dated April 28, 2009 and approved by USEPA Region 2 on May 8, 2009);
- Quality Assurance Project Plan (QAPP) dated April 8, 2009 and approved November 24, 2009;
- Health & Safety Plan dated August 2008; and
- Data Management Plan dated March 12, 2009.

These documents provided a comprehensive summary of the site setting, discussed previous investigations, presented Conceptual Site Models (CSMs) and study questions, defined the overall RI/FS process, presented the Phase 1 RI/FS Scope of Work, described the risk assessment and remedy evaluation approach, and presented the major components of the overall RI/FS. These documents served to guide the Phase 1 work that was conducted throughout 2009 and into 2010. The Phase 1 Site Characterization report (submitted under separate cover) provides a complete summary of the findings of the Phase 1 work. This Phase 2 Addendum to the Work Plan supplements the project documents. A QAPP amendment has been prepared to further guide the Phase 2 program and is submitted under separate cover.

As defined in the AOC/SOW, the RI/FS is conducted to gather sufficient data and information to characterize the horizontal and vertical distribution of chemicals of potential concern (COPCs), and the fate, transport and biouptake of COPCs in the BCSA, to support the selection of a remedy that will reduce risks to human health and the environment associated with hazardous substances at the BCSA. The purpose of this Phase 2 Work Plan Addendum is to identify data needs related to the Site-specific study questions (presented in the RI/FS Work Plan and Phase 1 report) based on Phase 1 findings, and to define the scope of work proposed in Phase 2 to address these data needs. Data collected in Phase 2 will also facilitate further refinement of the conceptual site models (CSMs) that were developed in the RI/FS Work Plan and updated based on Phase 1 findings, as described in the Phase 1 report.

1.3 Work Plan Addendum Organization

The overall Work Plan addendum organization follows the RI/FS Guidance, although adaptations were made as needed to match the specific needs of an evaluation of a megasite watershed study area. This Phase 2 addendum is organized as follows:

- Section 2 describes the Phase 2 RI/FS Rationale and Approach
- Section 3 summarizes the proposed Phase 2 Scope of Work.
- Section 4 presents the ecological risk assessment (ERA) approach.
- Section 5 presents the human health risk assessment (HHRA) approach.
- Section 6 presents the proposed feasibility study (FS) scope of work.
- Section 7 presents the project schedule.
- Section 8 presents references used in the development of this Work Plan addendum.

SECTION 2

PHASE 2 - RI/FS RATIONALE AND APPROACH

2.1 Phase 2 RI/FS Approach

The Phase 2 Addendum to the Work Plan presents the study design for Phase 2 based on the findings of Phase 1. This addendum emphasizes risk assessment needs, refinements of the CSMs for physical, chemical, and biological systems, and early considerations of potential remedial alternatives to provide the information necessary for the FS. In particular, an evaluation of the roles of the upland tributaries and marshes in COPC fate and transport in the BCSA will be an important aspect of the Phase 2 program. Data from Phase 1 have been analyzed and evaluated to identify additional data needs related to the Site-specific study questions (as presented in Section 1.2 of the Phase 1 report) and to develop effective methods and analyses to address these data needs in Phase 2. For example, the refined understandings of the tidal prism and sediment deposition obtained in Phase 1 have been used to design Phase 2 surface water and sediment coring programs that will accurately capture the temporal and spatial scales of interest.

Fundamental management principles and agency guidance (USEPA, 1988; USEPA, 2005a, National Academies, 2007) for large-scale (watershed/landscape level) investigations were identified at the start of the project to provide focus throughout the scoping activities and subsequent RI/FS activities. The following aspects of this guidance have been incorporated into the RI/FS and are reflected in the project documents, including this Phase 2 Work Plan addendum:

- Strong emphasis on sound CSMs initiated before the RI/FS AOC through the implementation of the Scoping Activities Work Plan (ELM, 2007) and continually updated throughout the RI/FS process as additional data and understanding are gained;
- Emphasis on long-term monitoring, which is reflected in the RI/FS sequence through the early initiation and continuation of monitoring programs;
- Pursuit of optimized characterization schemes through a multi-phased RI/FS and ongoing attention to adaptive site management (ASM) principles;
- Close integration of the RI and FS components beginning in Phase 1 of the RI; and
- The use of work groups to facilitate planning.

Application of these principles to the RI study approach facilitates development of a robust data set to characterize risks and evaluate remedies. In identifying data needs and designing studies for the BCSA, both risk and remedy have been considered to evaluate the importance of the data collection and evaluation tools (e.g., models). These considerations have been incorporated into the Phase 2 study design, and will be considered iteratively throughout all subsequent phases of the RI/FS to support sound risk-based management decisions and to develop effective remedies.

2.2 Refined Data Quality Objectives

A critical component of the RI/FS study design entails the completion of the seven-step systematic planning process in accordance with USEPA's *Guidance on Systematic Planning Using the Data Quality Objectives Process* (USEPA QA/G-4, 2006). This process, which was documented in the QAPP, ensures that due consideration is given to the overall problem addressed by a study component, inputs to the problem, study boundaries, performance criteria, and study design. The preliminary DQOs have been reviewed and revised based on the findings of the Phase 1 data collection program and comments received from the USEPA. Appendix E to the QAPP addendum presents the revised DQO's.

2.3 Evaluation of Field Analysis Techniques

Subsequent to the completion of Phase 1 field activities, an evaluation was conducted to determine if the use of an on-site laboratory or other mobile analytical devices would facilitate a more cost-effective and high-resolution determination of COPC distributions in the BCSA than the current approach of using an off-site laboratory for analyses. More specifically, could on-site analysis of indicator chemicals provide benefits to the investigation not currently afforded by off-site analysis and provide high-resolution results in accordance with project reference limits and data quality objectives? Two options were evaluated 1) the use of an on-site laboratory and 2) mobile analytical devices.

On-site Laboratory

Generally, on-site laboratory facilities provide benefit by 1) supplying customized and individual service to the project, and 2) allowing for the formulation of real-time decisions or adjustments to the project scope based on observed site conditions. Off-site analytical services are currently being provided by three Test America laboratories. During Phase 1 of the RI, Test America was able to accommodate the volume of samples generated and produce results within the QAPP-specified timeframe. Furthermore, project reference limits were met in part due to up-front efforts during methods development to resolve any issues related to sample matrix. Test America is familiar with BCSA samples and is able to provide customized service to the project.

Current sample design does not require real-time decision making or adjustment based on observed concentrations of indicator chemicals. Boundaries of the BCSA are largely defined by the waterways and marshes of the system and therefore the "step-out" type delineation strategies of some upland sites are largely not applicable. This type of sampling program may be beneficial as hot spot areas, if present, are further defined for remediation purposes, but currently data are being assessed on a site-wide basis to further refine CSMs, assess risk, and guide later phases of the RI. Additionally, real-time decisions are required/cost-effective when sampling costs are elevated due to inaccessibility (e.g., samples are being collected from significant depth) or when specific equipment/personnel are required and remobilization is not cost-effective (e.g., packer sampling groundwater in boreholes or equipment required for ongoing site remediation). Samples being collected in the BCSA are accessible. Sediment samples are not proposed to be collected from depths greater than 6 feet and the equipment required for sampling all matrices is easily remobilized, if required.

Given the to-date and proposed Phase 2 analytical requirements of the BCSA, an on-site lab does not provide sufficient benefit to justify associated cost and potential reduction in data quality.

Mobile Analytical Devices

As with on-site laboratories, mobile analytical devices, such as those using X-ray fluorescence spectrometry, are useful in situations where real-time data is a necessity. As detailed above, the need for precise and reliable data supportive of project DQOs is higher priority than instantaneous results.

SECTION 3

PHASE 2 - REMEDIAL INVESTIGATION

SCOPE OF WORK

This section discusses the scope of Site characterization and related work elements that will occur in Phase 2. In addition to field tasks, desktop study and reporting tasks are included; 14 tasks in all are described in this section. For each task, an overview of the conceptual basis and rationale for characterization is provided, followed by a discussion of the investigative methods. Implementation details are provided in the QAPP/FSP, as amended for Phase 2.

The task structure for the overall RI/FS project is provided in Table 3-1. Tasks are broken out by activity (e.g., remedial investigation, risk assessment, or feasibility study) and phase. The Phase 1 scope was focused on the physical features of the study area (e.g., topography, bathymetry, hydrology), and characterization of the chemical and non-chemical stressors in surface water, sediment, and biota of the waterways. An initial evaluation of the marsh sediments was also conducted.

As an overview, Phase 2 is directed towards a more detailed assessment of hydrodynamics and associated sediment transport and deposition dynamics, refining the COPC distribution in the waterways, characterizing COPCs in the marshes throughout the study area, as well as interactions between the marshes and waterways. The sediment balance in the BCSA will be further quantified. Sampling of surface water, sediment, and biota for a focused set of conventional and non-conventional parameters in the waterways over the entire BCSA and three candidate reference areas is also included in the proposed scope of work.

The data collected for Phase 1 of the RI provided the first comprehensive assessment of the environmental condition of the BCSA and have been used to perform the following tasks:

- preliminary characterization of horizontal and vertical gradients of COPCs;
- initial evaluation of the probable relative mobility and potential bioavailability of COPCs in the four major study segments;
- completion of screening level risk assessments;
- identification of COPCs;
- refinement of the study questions, DQO's and CSMs;
- selection and preliminary characterization of reference areas;

- support the preparation of a modeling plan;
- support the initial Site-specific FS activities;
- establish the current baseline conditions and initiate long-term monitoring of the BCSA with concurrent and co-located surface water, sediment, and biota samples; and
- provide the basis for the detailed Phase 2 Site characterization.

The Phase 1 report presents the findings in relation to study questions #1 through #7; study questions #8 through #12 relate to the remedy evaluation and will be addressed in detail during the Phase 2 FS activities.

Phase 2 is directed towards completing the characterization of the distribution of COPCs in waterways and marshes, to the extent necessary to complete the risk assessments and the identification/screening of remedial alternatives. The level of effort in delineation has been weighted among study segments, habitats, and sub-habitats based on the analysis of the Phase 1 data. In addition, Phase 2 will support the following:

- identification and some quantification of the dominant factors controlling the bioavailability and biological uptake of COPCs;
- characterization of ongoing sources detectable in the tidal portion of the BCSA, and referrals to the USEPA for further action where warranted;
- assessment of the exchange of surface water and groundwater in the LBC area;
- furtherance of the risk assessments, subject to completion after Phase 3;
- field data calibration and validation of models selected in the modeling plan;
- refinement of the answers to the study questions, DQO's and CSMs;
- geotechnical and stability analyses to support screening and evaluation of potential remedial alternatives;
- evaluation/screening of remedial alternatives by BCSA segment (UBC, MBC, BCC and LBC; and some combinations across the tidal portion of the BCSA), to the extent practical based on Phase 1 and Phase 2 data;
- completion of the IRM Letter Report; and

- further description of the baseline conditions and trends (concurrent and co-located surface water, sediment and biota samples) in the BCSA and reference areas.

The Phase 2 work will also focus on the characterization of the BCSA sediment dynamics through the evaluation of a multiple lines of evidence approach. As discussed in an August 4, 2010 work session with the USEPA review team, sediment transport deposition and resuspension dynamics in this estuarine waterway and marsh system are complex. Changes occur over long time frames and are temporally and spatially variable. Consequently, the multiple lines of evidence have been augmented in this revised Phase 2 Work Plan Addendum to include the elements outlined below.

Line of Evidence	Analysis/Tool
Sediment/Sediment Bed Characteristics	Particle Size Distribution Sediment Profile Imaging Core Logs
Water Column Flux	Moored Stations Transecting Mobile Monitoring
Suspended Sediment Characteristics	LISST (Particle Size Distribution) Total Suspended Solids Turbidity Acoustic Back Scatter
Suspended Sediment Flux	Moored Stations Transecting
Geochronology/Sediment Bed Chemistry	Cs^{137}, Pb^{210}, Be^{7} COPC Profiles
Upland Runoff	Runoff Modeling Literature Tributary Measurements of Flow, TSS, Bedload
Direct Empirical Measurements	Sedflume Sediment Elevation Tables Sediment Traps High Frequency Acoustic Doppler Velocimeter

Each of these lines of evidence will be evaluated separately and in combination based on the Phase 1 and Phase 2 data.

The findings from Phases 1 and 2 of the RI/FS will inform the development of a scope of work for Phase 3, consistent with the management principles discussed in Section 2. Phase 3 will be directed toward collection of data to support the completion of the Site-specific risk assessments and the detailed evaluation of remedial alternatives. That work will likely include more detailed evaluation of particular areas (waterways or marshes) within some study segments, based on the pattern of COPC distribution, movement, biouptake, and other data needs.

Figures 3-1 through 3-4 present the proposed Phase 2 sampling scopes in multiple media with a focus on individual study segments (i.e., UBC, MBC, BCC, and LBC). Each figure presents sampling and monitoring locations for i) hydrodynamics, ii) surface water, iii) sediment (waterways and marshes), iv) groundwater, and v) biota. The sampling locations across several media are shown on a single figure to emphasize the intentional co-location of sampling points across media. This co-location has been specified to support cross-media comparisons of COPC concentrations and related data. Note that Phase 1 sampling locations are also shown on these figures for ease of reference. Figures within each subsection provide sample locations for Phase 2 alone.

Section 3.6 of the Phase 1 report reviewed chemical analytical data collected during the Phase 1 program to identify COPCs that are above screening benchmarks and reference area concentrations in surface water, sediment, and tissue samples (primary COPCs) or that are above screening benchmarks and reference area concentrations in two environmental media (secondary COPCs). The primary and secondary COPCs are shown below, by media. The purpose of identifying primary and secondary COPCs was to provide focus to both the analysis and presentation of the Phase 1 data, as well as the analytical parameter list to be used in the Phase 2 program. The primary and secondary COPCs will be analyzed in all relevant media in addition. The Phase 2 program includes a percentage of samples (~ 10 to 20 percent) subject to a minimum number of samples for each media and reach that will be analyzed for the full analytical suite used in Phase 1. The Phase 1 report contains a full description and rationale for the analytical program for Phase 2. The project QAPP, as amended for Phase 2, reflects these changes to the analytical program.

	Surface Water	Sediment	Tissue
Primary COPCs			
Mercury	X	X	X
Methyl Mercury	X	X	X
PCBs	X	X	X
Secondary COPCs			
TAL Metals	X	X	

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The Phase 2 program proposes to use the same analytical methods that were implemented in Phase 1 for TAL metals, mercury, and methyl mercury. The Phase 1 program included analysis for PCBs by Aroclor mixture, and the Group agreed to evaluate the usefulness of congener analysis for the Phase 2 program. The term congener refers to 209 individual PCB compounds with varying chemical structures. PCBs were originally produced as specific mixtures of congeners known as Aroclors, and can be analyzed and quantified either as Aroclor mixtures or as individual congeners. There are a number of reasons for the decision to use PCB Aroclor analysis as summarized below.

- **Aroclor data match the available toxicity criteria and therefore can be used directly to quantify risks for baseline and remedial alternatives analysis.** The toxicity criteria that will be used to assess human health and ecological risks are based primarily on Aroclor-specific toxicity data. Importantly, for example, EPA has developed cancer slope factors and a non-cancer RfD for PCBs that are based on data for Aroclors. These values are published in EPA's Integrated Risk Information System (IRIS) database. Based on EPA OSWER directives, toxicity values published in IRIS are given first preference for use in risk assessment. No PCB congener-based toxicity values are published in IRIS. Although some congener-specific toxicity data are available in the general literature, not enough is available to fully characterize risks based on congener data alone. Alternate proposals to use toxic equivalency (TEQs) for a subset of PCB congeners termed dioxin-like congeners (DLCs) along with the cancer slope factor for 2,3,7,8-TCDD remains unsettled and somewhat controversial within the scientific and regulatory community (Carlson *et al*, 2009; Silkworth *et al*, 2005; GE, 2010) and highly uncertain. For these reasons, the Group concludes that Aroclor data should be used most reliably to assess risks in the BCSA.

  Aroclor data will be sufficient to both characterize the nature and the magnitude of baseline risks in the BCSA and to evaluate the risk reductions of potential remedial alternatives.

- **Aroclor data needed for trend analysis and post-remedy monitoring.** Historic PCB data that will be used in long term concentration trend analysis for surface water, sediment and biota is all derived from Aroclor analysis. Consequently, to meet USEPA guidance on evaluation of concentration trends, Aroclor data is required. Also, given analytical issues, cost, and risk interpretability, any post-remedy monitoring will almost certainly be based on Aroclor rather than congener data, as is typical of other sediment sites with PCBs. The Group finds that congener data will not provide information that is useful for establishing the pre-remedy baseline against which post-remedy conditions will be assessed.

- **Congener data would have very limited application in the development and assessment of risk management alternatives for the Site.** Because congener data can be used in the risk assessment process only with a high degree of uncertainty, they would have limited value in the development of risk management decisions for the site. The Group finds that collection of these data will not contribute to risk management decisions at the Site beyond what is provided by Aroclor data.

- **Source identification or allocation is not an objective of the Remedial Investigation.** Congener data can be useful if investigations are being conducted to support forensic evaluations related to source apportionment and allocation. This is not, however, an objective of the RI in the BCSA. The goal of the RI for PCBs is to collect sufficient data to understand the nature and magnitude of the risks posed by PCBs and other substances and to evaluate how those risks might change under different remedial alternatives. Source identification is directed towards on-going sources that can lead to recontamination after a remedial action. In addition, in a well mixed estuary where the primary PCB sources are likely to date back to the 1950s and 1960s, the PCB signatures are likely to be highly overlapping in relation to source areas. Therefore, Aroclor data are adequate to provide the necessary information to achieve risk-related objectives.

- **The current EPA method for performing the PCB congener analysis can result in uncertainties regarding the accuracy of the calculated PCB TEQs.** If PCB congener data were collected, risks would need to be evaluated using the TEQ approach noted above. The TEQ approach, by definition, requires analysis of individual DLCs, including PCB congeners that are DLCs. The only method of which we are aware that is used to analyze the dioxin-like PCB congeners is EPA's Method 1668 -- Chlorinated Biphenyl Congeners in Water, Soil, Sediment, Biosolids, and Tissue by HRGC/HRMS. EPA Method 1668A was originally developed in 1999, and some additional method adjustments were made in August 2003 when the method was renamed Method 1668A, and in November 2008 when the method was renamed Method 1668B -- [1]. Although EPA Method 1668A has undergone an interlaboratory validation study, EPA Method 1668B has not been validated as called for by EPA's Agency Policy Directive No. FEM-2005-001, Ensuring the Validity of Agency Methods – Methods Validation and Peer Review Guidelines (2005) ("Validation Policy")[2], or FEM Document No. 2005-01, Validation and Peer Review of U.S. [EPA] Chemical Methods of Analysis ("Validation Guidance")[3]. An inter-laboratory validation study of Method 1668A conducted for EPA by qualified labs in 2003 to 2004 (originally reported in November 2008[4] and then revised in May 2010[5]) indicates that Method 1668B, although

[1] http://water.epa.gov/scitech/swguidance/methods/upload/M1668C_11June10-PCB_Congeners.pdf

[2] http://epa.gov/osa/fem/pdfs/Method_Validity_Policy_092705.pdf

[3] http://epa.gov/fem/pdfs/chemmethod_validity_guide.pdf

[4] http://www.epa.gov/waterscience/methods/method/files/1668Ato1668B-valdiation.pdf

[5] http://water.epa.gov/scitech/swguidance/methods/upload/Method-1668A-Interlab-Study-Report-05-14-2010.pdf

published in the Federal Register as promulgated and approved, is problematic and requires further improvement. Some of these improvements may have been addressed by Method 1668C (May 2010), but this revised method is not promulgated or approved at this time. In addition, any quality control issues with the methods may be compounded by matrix interferences that vary across the BCSA, such as salinity and high organic concentrations (both natural and contaminants). Also, the elevated PCB concentrations in a relatively large number of sediment samples can pose analytical problems. The Group, therefore, finds that the analytical uncertainties surrounding PCB congener analysis will render these data of limited utility to support risk management decisions in the BCSA.

For all of the above reasons, the Group concluded that Aroclor analysis is the better match for the BCSA conditions and congener analysis will not provide additional data that will influence the risk analysis, especially taking into account the substantially increased time and costs associated with analyzing for and interpreting congener-specific PCB data from the difficult sediment matrix in the BCSA.

The trade-offs of PCB Aroclor analysis vs. congener analysis has been added to the DQO analysis. The DQO tables found in the QAPP further describe the rationale for the use of Aroclor analysis.

In addition to the Aroclor analysis, the Group will use the congener data from the UOP Site (located within the BCSA) work to preliminarily evaluate the potential utility of PCB congener data in some elements of the risk assessment.

The following tasks fully describe the proposed scope of work for the Phase 2 program.

3.1 Task 1 – Site Hydrology/Hydrodynamics/Sediment Transport

The Phase 2 Hydrology/Hydrodynamics/Sediment Transport program (hereafter referred to as the Hydrodynamics Program) will consist of seven subtasks: a) continued moored station hydrodynamic and water quality monitoring; b) collection of transecting data; c) suspended solids characterization; d) dye tracer study; e) high frequency monitoring of sediment bed flow velocities and suspended solids; f) monitoring of upland freshwater inputs; and g) Sedflume evaluation. Task 1 addresses Study Questions 1, 2, 4 to 6, and 9 to 12, which focus on stressors and their sources, sediment and chemical fate and transport, and remedy considerations.

3.1.1 Task 1A – Moored Hydrodynamic and Water Quality Monitoring Stations (RI-P2-T1A)

Conceptual Basis and Rationale

Task 1A is a continuation of the long-term hydrodynamic and water quality monitoring instituted in the BCSA during the Phase 1 program. As is described in the Phase 1 Work Plan

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(Geosyntec/Integral, 2009), this monitoring is designed to address the following components of the hydrodynamic CSM: a) hydrodynamics, b) sediment transport dynamics, and c) general water quality. The moored stations provide for accurate, empirical estimates of flow velocities and flux, tidal prism, and sediment flux by providing a temporally robust dataset at several locations distributed across the system. Vertical and lateral profiles of velocity and suspended sediment will be collected at these locations at a frequency sufficient to capture changes brought about on the basis of i) diurnal/semidiurnal tidal cycles, ii) biweekly (i.e., spring-neap) tidal cycles, iii) seasonal cycles, and iv) storm induced variability. Collectively, these data will provide a robust understanding of the system hydrodynamics, thus supporting further refinement of the physical system CSM and future analysis efforts.

Because sediment accumulation in estuarine wetland systems is a long-term process, it is important to assess sediment transport in the BCSA over multiple seasons and years. The ongoing Phase 1 hydrodynamic monitoring, combined with continued monitoring in Phase 2 and Phase 3, will provide a multi-year record of BCSA hydrodynamic and sediment dynamics such that processes and trends can be better understood. Further, this multi-year record will provide a greater opportunity to capture a range of conditions (e.g., rainfall conditions, major storm events, tides, etc). In addition, differences in volumetric flow rates, sediment fluxes, and water velocities will be combined to develop a quantitative description of marsh and waterway exchange in the BCSA.

Scope of Work and Investigative Methods

The five moored hydrodynamic/water quality stations already installed at the Site (MHS-01, MHS-02, MHS-05, MHS-06, MHS-07; Figure 3-5) will continue to record both hydrodynamic and water quality parameter data over the course of Phase 2 (i.e., approximately 1 year). In addition, the two temporary moored stations (MHS-03 and MHS-04) will again be installed short-term (i.e., 1 to 2 months, or until a periodic discharge of storm water occurs) to measure differences in volumetric and sediment flux during discharge events from the NJSEA storm water management system. MHS-03 will be located at the northern end of LBC, whereas MHS-04 will be located in southern MBC on the opposite side of the NJSEA outfall from MHS-05.

Section 8.1.1.2 of the Phase 1 Work Plan details the instrumentation for each of the moored stations. The Phase 1 data to date suggest that suspended sediment in the BCSA water column consists of substantive proportions of both inorganic and organic material. To better characterize the suspended sediment in the BCSA water column, the moored stations will be outfitted with additional optical instrumentation to provide a more complete characterization of the composition of the suspended particulates. This instrumentation will consist of WET Labs ECO Fluorometers (FLSBs) to quantify chlorophyll-*a*. The project documents (QAPP/FSP/SOPs) have been updated to reflect these changes. In addition, suspended sediment particle size distributions will be measured over multiple tidal cycles at two selected moored stations during the deployment of the temporary moored stations using a Laser *In Situ* Scatter and

Transmissometry (LISST) instrument. This instrument relies on varying degrees of laser diffraction to differentiate between particle sizes. The selection of the two moored stations for the LISST deployment will be determined based on an analysis of the complete Phase 1 data set.

3.1.2 Task 1B – Collection of Transect Data (RI-P2-T1B)

The mobile monitoring of velocity and turbidity across channel transects to evaluate discharge and sediment flux completed during Phase 1 will be repeated in Phase 2. However, in Phase 2, the transect monitoring will be modified to include: 1) additional focus on the evaluation of storm surge events when energy inputs to the system (wind-driven tidal surge from coastal storms and upland discharge) are among the highest; and 2) evaluation before, during, and after storm surge events of the hydrodynamics of pools located at waterway meander bends. These elements are presented respectively as subtasks 1B.01 and 1B.02 below.

3.1.2.1 Task 1B.01 – Storm Surge Transect Monitoring Events

Conceptual Basis and Rationale

The objective of the Phase 2 storm surge transect monitoring events is to assess water and sediment exchange within the system, with the Hackensack River, and from upland sources under the typical range of conditions and high energy conditions. These transect monitoring events will be augmented with extensive sampling of total suspended solids (TSS) to refine the estimates of sediment flux. Additionally, the storm surge-focused transect program described herein will be performed in concert with a COPC-focused surface water sampling program intended to augment the understanding gained from Task 1B.01. The surface water sampling component, which will include TSS sampling and both automated and manual components, is described in Sections 3.2.1.3 and 3.2.2.4. During two separate storm surge events, velocity and turbidity measurements across channel transects adjacent to the moored stations will be monitored for a several-day period in an effort to evaluate water and sediment flux across both rising and falling water levels. To the extent feasible, the sampling will attempt to capture a major event, such as a nor'easter, that generates high winds off the coast and into Newark Bay along with the associated storm tide surge and heavy rainfall. Sampling crews will be on standby to mobilize to the Site should the weather forecast suggest the high likelihood of a major storm event.

The series of transect measurements will be used to quantify the water discharge and sediment flux at the time of the transect measurements. The discharge and sediment flux estimates will then be compared to the simultaneous velocity and turbidity measurements at the moored station to develop an empirical relationship between the datasets. This relationship will be used to extrapolate longer-term water discharge and sediment flux over the course of the full storm surge event in the system based on the moored station velocity and turbidity measurements collected during the monitoring period.

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Scope of Work and Investigative Methods

Mobile monitoring consisting of velocity and turbidity measurements will be performed across a channel transect adjacent to the moored stations. In addition, *in situ* suspended sediment particle size distributions will be measured using a LISST instrument. The data collected to date confirm the understanding that the BCC represents the primary point of BCSA water and sediment exchange with the Hackensack River. As a result, MHS-01 (on BCC) will be the focus of the transect monitoring. MHS-06 (in UBC, near Paterson Plank Road) will be frequently monitored to assess how influences of the storm surge manifest within the BCSA. To the extent feasible, stations MHS-02 (LBC), MHS-05 (southern MBC), and MHS-07 (northern UBC) will be monitored; however, monitoring of stations MHS-01 and MHS-06 will be prioritized, and monitoring at stations MHS-05 and MHS-07 will be less frequent. Because the LBC exchange with the Hackensack River is less important to the hydrodynamics/sediment dynamics in MBC and UBC and access to LBC is hindered during high tide by the Transco pipeline bridge, station MHS-02 will be monitored only when logistically feasible.

The transect monitoring will be conducted as frequently as is feasible while ensuring that the work is completed in a safe manner. The majority of the monitoring will be performed during daylight hours, and monitoring at night will be limited due to the potential hazards associated with working in darkness under storm conditions (e.g., heavy rain and wind) on a small vessel. The monitoring will continue for a period of up to 4 days, but may be terminated earlier if the monitoring demonstrates that the falling tide levels of the storm surge recession have been captured.

Samples for TSS analysis will be collected during the transect monitoring events. TSS samples will be collected during each transect measurement, at the location of the moored station, at the depth of the water quality probe deployed at the station. For a minimum of 20% of the velocity and turbidity transect measurements at MHS-01, six TSS samples will be collected along the transect. The six TSS samples will be collected at two depths at each of three locations across the transect (thalweg and at the midpoint between the thalweg and each bank). The samples will be collected with a Niskin bottle at the depths of the two water quality meters at MHS-01. To the extent feasible, transect TSS samples will also be collected along the transect at MHS-06 (3 lateral locations with two depths each) during a subset of the transect velocity and turbidity measurements at this station. These samples will also be taken at the thalweg and at the midpoint between the thalweg and each bank, at the depths of the two water quality meters at MHS-06.

Note that in addition to the TSS sampling described herein, additional TSS sampling and turbidity measurements will be performed as a component of the surface water COPC sampling during the transect monitoring event as described in Section 3.2.2.4. Salinity and temperature will be recorded.

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The protocols for the Task 1B.01 program are detailed in the project documents (QAPP/FSP/SOPs).

3.1.2.2 Task 1B.02 – Waterway Pool Transect Monitoring

Conceptual Basis and Rationale

Transecting in the waterway pools will facilitate characterization of the hydrodynamics within these features. The pools are significant features relative to the typical channel morphology. They reflect the vertical dissipation of energy, where horizontal water flow is forced to alter course at the bend, where banks stabilized by *Phragmites* resist erosion. The size of these pools may be a relic of historically higher flows (and energy) in the system.

Transect monitoring under Task 1B.02 will characterize the velocity regime in these hydrodynamically complex features. Under conditions approaching a spring tide, velocity measurements will be taken across channel transects at three waterway pools in the BCSA (Figure 3-5). The transecting will monitor conditions in the pools over the 12-hr tidal cycle. The series of transect measurements will provide a characterization of the vertical profile of water velocity across the channel transect at the waterway pools under conditions ranging from low to high tide.

Scope of Work and Investigative Methods

Transect monitoring consisting of velocity measurements will be performed across a channel transect at the three waterway pools shown in Figure 3-5; the selected pools are relatively large yet also reflect a broad spatial range, from southern MBC to central UBC. The waterway pool transect monitoring will be integrated with the storm surge monitoring described in Task 1B.01, whereby the pools will be monitored during the surge event as well as immediately before and after the event to capture typical conditions. The transect monitoring will be conducted as frequently as is feasible while ensuring the work is completed in a safe manner. The monitoring will continue for a period of 12 hours during the surge event and, to the extent feasible, will be performed under tide conditions approaching a spring tide.

The protocols for the Task 1B.02 program are detailed in the project documents (QAPP/FSP/SOPs).

3.1.3 Task 1C – Suspended Solids Characterization (RI-P2-T1C)

Conceptual Basis and Rationale

The Phase 1 data indicate that the suspended particulates in the BCSA water column consist of two predominant size fractions and suggest the presence of substantive proportions of both inorganic and organic phases. Preliminary results suggest that BCSA suspended solids

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variability is, in part, controlled by tidal processes and runoff from precipitation, and that the relative contribution of the organic suspended sediment is likely to be seasonally dependent. Understanding the composition and variability of the suspended solids is critical to understanding the sediment balance for the BCSA and, in turn, past and potential COPC transport.

A detailed characterization of the relationship between TSS and turbidity measurements as a function of season and tidal phase is needed to extrapolate continuous turbidity measurements at the moored stations and, in turn, quantify sediment fluxes. Further analysis of the Phase 1 data suggests that TSS concentrations in the water column may be correlated to the acoustic backscatter (ABS) data collected by the acoustic doppler current profiler (ADCP) and acoustic doppler velocimeter (ADV) instruments deployed at the moored stations. Collection of additional TSS data will enable detailed characterization of the relationship between TSS and ABS data, which may provide a secondary means for extrapolating suspended solids concentrations from the long-term monitoring data at each of the moored stations.

Scope of Work and Investigative Methods

A bi-monthly (every other month) sampling program will be instituted to collect TSS and organic carbon samples across a range of tidal, precipitation, and seasonal conditions. The program will involve collection of samples for TSS, total organic carbon (TOC), dissolved organic carbon (DOC), and particulate organic carbon (POC) analysis at each of the five long-term moored stations during flood, ebb, high, and low tide conditions, every other month. The samples will be collected with a peristaltic pump and tubing at the depths of the water quality meters at each of the moored stations. The samples will be analyzed for TSS, POC, DOC, and TOC concentrations. In addition to this program, TSS samples will be collected as part of transect monitoring of flow, turbidity, and COPC concentrations during two storm surge events, as described for Task 1B.01 and Task 2B.04 in Section 3.1.2 and Section 3.2.2.4, respectively. Collectively, these sampling efforts will provide a robust dataset for calibrating the turbidity and ABS measurements at each of the moored stations to TSS concentrations over the range of conditions present in the BCSA. The addition of the FLSB and LISST measurements (Task 1A) combined with the quantification of TSS, POC, and TOC will provide a good characterization of the suspended solids composition (e.g., particle size and organic fraction).

The protocols for the Task 1C program are detailed in the project documents (QAPP/FSP/SOPs).

3.1.4 Task 1D – Dye Tracer Study (RI-P2-T1D)

Conceptual Basis and Rationale

A dye tracer study will be completed to evaluate the hydraulic connection of various features of the BCSA. Analysis of the Phase 1 hydrodynamic data to date, as well as other Phase 1 and

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historic data (e.g., COPC distributions in sediments; historic observations of poor flushing of sewage discharges to UBC and MBC), suggests that UBC is not completely flushed with each tidal cycle. This phenomenon has significant implications for past, present and future COPC fate and transport, as well as for remedial alternative analysis and design. A primary objective of the dye tracer study is to assess the extent of tidal flushing and mixing in UBC by injecting dye in UBC and monitoring its migration through the system over time. Secondary objectives include assessment of the degree of hydraulic connection between marshes, tributaries, and waterways; evaluation of the exchange of water with the Hackensack River; and assessment of the connection between LBC and the rest of the system. Measured dye flow paths and dispersion rates will provide quantitative data that will be used to verify the hydrodynamic CSM. The data from the dye study will be used to validate calculated dispersion rates and flushing analyses based on moored station water quality data (salinity, temperature). Further, should numerical hydrodynamic modeling be completed, the dye study data set will be considered along with other site data to calibrate the numerical model.

Scope of Work and Investigative Methods

The dye study will involve two separate dye injections to evaluate flushing and mixing. These two injections will evaluate neap tide (least tidal flushing) and spring tide (greatest tidal flushing) conditions. Each investigation will involve injection of fluorescein dye in UBC (Figure 3-5) at high slack tide followed by up to 4 days of sample collection. Note that in relatively clear water, fluorescein is visible to the naked eye. Given the murky conditions at the BCSA, the dye may be visible for a short period of time upon initial release. It should be visually undetectable within a few hours.

Prior to the field effort, water samples will be collected from the BCSA for laboratory benchtop testing to determine the dynamic range and sensitivity of Wetlabs ECO-triplet fluorescein fluorescence sensors within the substantial background turbidity inherent to the BCSA water column. If the preliminary testing confirms that the sensors are appropriate for use in the BCSA, a series of sensors will be deployed on moored stations MHS-06, MHS-05, and MHS-01 to provide continuous monitoring of dye concentrations (Figure 3-5). An alternate approach will be evaluated if the measurements with the sensors experience difficulty.

Dye concentrations will also be monitored throughout the primary waterways and smaller waterways in selected marsh areas (Eight Day Swamp and Walden Swamp) of the BCSA over the course of each investigation using sensors deployed from a boat. The vessel monitoring will provide real time data on the dye progression through the system and will direct the sampling crew on where to focus ongoing monitoring efforts. The vessel monitoring will initially focus on UBC where the dye is injected. During the falling tide immediately following the dye injection, monitoring will focus on tracking the dye movement down the main channel and, as accessible and appropriate, into marsh tributaries. Thereafter, the migration of the downstream edge of the dye front, as well as monitoring dye migration back up into the system and marshes with rising tides will be monitored. Monitoring of LBC during high tide will be limited by access constraints associated with the Transco pipeline bridge; however, at a minimum, dye concentrations will be periodically monitored in LBC downstream of the bridge. Additionally, alternative approaches, such as hand deployment of the sensor at the culvert underlying the EnCap road and/or deployment of a dedicated jon boat in LBC, will be considered to facilitate monitoring of dye migration in LBC.

Throughout the vessel monitoring period, discrete water samples will be periodically collected by boat throughout the system and analyzed for fluorescence excitation-emission matrices (EEMs) on an ISA-SPEX 322 Fluorolog spectrofluorometer. The discrete samples will be used for the calibration of the continuous monitoring results at the three deployed sensors and the vessel-mounted sensor. The locations and number of discrete samples collected will be determined in the field based on the observed dye flow path.

The protocols for the Task 1D program are detailed in the project documents (QAPP/FSP/SOPs), as amended for Phase 2.

3.1.5 Task 1E – High Frequency Monitoring of Sediment Bed Flow Velocities and Suspended Solids in Waterways (RI-P2-T1E)

Conceptual Basis and Rationale

Sediment resuspension is a potentially important mechanism influencing sediment and contaminant fate and transport within the BCSA. A thin veneer of unconsolidated sediments at the surface of the sediment bed which is routinely resuspended to varying degrees during the rising and falling tides is common in estuarine systems. Similar sediments in the water column deposit to the sediment bed surface during slack tide stages. Some of the near surface sediments that are routinely suspended and deposited by tidal action are typically referred to as the "fluff layer". Several lines of evidence from the Phase 1 data (e.g., water column turbidity and TSS concentrations, SPI images, measured flow velocities) suggest that the fluff layer in the BCSA is thin (<1 cm), a finding that is consistent with the low energy of this type of estuarine environment.

Task 1E involves the application of high frequency ABS measurements using an ADV instrument to provide a detailed assessment of sediment resuspension dynamics. The primary function of the ADV is to quantify flow velocities near the sediment bed at high frequencies; however, the high frequency ADV data can be used to quantify near bed turbulence and sediment dynamics, such that particle settling speeds and relative concentrations in response to tidal velocities can be determined. Task 1E involves the deployment of an ADV over a 24-hr spring tidal cycle at selected locations within the main waterway and marsh tributaries to quantify local, near-bed flow velocities and suspended sediment concentrations. The ADV will be programmed to take measurements at least every 0.1 seconds, allowing for a detailed understanding of the changes in near bed flow velocities and suspended sediment concentrations over the course of a tidal cycle. These data will allow for an evaluation of the degree of sediment resuspension and for the calculation of sediment settling speeds.

The combination of acoustic backscatter from the ADCP (long term) and ADV (short term high resolution) measurements provides a range of tools to look at near-bed (ADV) and water column (ADCP) variation in total suspended solids. The YSI's provide an additional proxy for TSS to help bolster the investigation. Integration of these values can be used to look at total water column transport of solids during tidal cycles. The magnitude of this transport during typical conditions gives us a volume magnitude of the fluff layer.

The ADV additionally gives a bed "altitude" measurement. The variation of this bed elevation is directly correlated to the thickness of the layer in motion. Preliminary results suggest a layer on the order of few millimeters, which is consistent with preliminary water column transport analysis.

Analysis of Sediment Profile Imaging (SPI) camera results from Phase 1 and SedFlume core analysis (see Task 1G) will be used as additional lines of evidence to support the quantification of the fluff layer thickness.

Scope of Work and Investigative Methods

An ADV will be deployed in the thalweg of tributaries to Nevertouch Marsh, Eight Day Swamp, and Walden Swamp (Figure 3-5). In addition, an ADV will be deployed at six locations in the main waterway, as shown in Figure 3-5. These locations coincide with most of the locations where cores will be collected for Sedflume analysis (Section 3.1.7) and high resolution geochronologic and chemical analyses (Section 3.3.6). The six main waterway locations include three locations within the subtidal zone and three locations on intertidal mudflats. In addition to providing for a detailed assessment of sediment re-suspension dynamics, this monitoring will provide for quantification of flow velocities in mudflats, which are substantial features within the BCSA. The velocity monitoring on the mudflats and in subtidal locations as described herein will complement velocity monitoring in the meander pools as discussed in Task 1B.02; hence, characteristic velocities for all three sediment bedform types will be measured.

Depending on availability, one to two ADV instruments will be used to monitor these stations and the equipment moved as needed such that each station is monitored for at least one tidal cycle. During each deployment, the ADV will take ABS measurements every 0.1 seconds over a minimum of one full tidal cycle. To the extent possible, these measurements will be taken at or approaching spring tide conditions. The ADV will be mounted on a specially-constructed platform (consistent with the existing platform for the ADV at MHS-07) to ensure that it remains stable throughout the course of the monitoring. The height of the ADV head will be positioned such that measurements can be obtained in very shallow depths (~15 cm). ADV deployment for

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Task 1E will occur opportunistically during other scheduled Task 1 activities (e.g., routine instrument download/maintenance).

The protocols for the Task 1E program are detailed in the project documents (QAPP/FSP/SOPs). Note that specific locations may be modified based on the findings of detailed analysis of Phase 1 hydrodynamic data.

3.1.6 Task 1F – Monitoring of Upland Freshwater Inputs (RI-P2-T1F)

Conceptual Basis and Rationale

The BCSA water budget and preliminary analysis of Phase 1 data quantifying water fluxes through the system demonstrate that the BCSA is tidally dominated and that fresh water flows are a small component of the water balance except during large precipitation events. Monitoring of flows and TSS concentrations in the east and west risers, coupled with modeling and literature-based estimates of TSS concentrations in urban runoff, suggests that upland runoff to the BCSA is a potentially important source of sediment to the tidal system. Task 1F involves monitoring at selected storm water outfalls/ditches to the BCSA to estimate representative long-term flow rates from these locations, to support the estimation of annual sediment loading, and to evaluate the storm hydrograph and quantify suspended solids concentrations during two major storm events. The data collected during Task 1F will provide an empirical basis for quantification of the water flow and suspended sediment flux associated with each of these inputs, as representative of the runoff from the uplands in the BCSA. These data, coupled with standardized runoff and soil loss methods for uplands (see RI/FS Work Plan), as well as other lines of evidence (e.g., response in turbidity levels at the moored stations to a storm event), will provide for a detailed understanding of the influence of freshwater inputs on the BCSA water and sediment balance.

Scope of Work and Investigative Methods

Freshwater inputs to the BCSA will be monitored at the six locations shown in Figure 3-5. These locations were selected based on the drainage areas delineated as part of the water budget, the point discharge reconnaissance survey conducted during Phase 1, and qualitative field observations of the relative significance of various outfalls/drainages to the system during storm events. Where possible, a pressure transducer will be installed and programmed to record water depth at a minimum of once every 10 minutes. The dimensions of the outfall or drainage ditch at each location will be measured, such that a depth-to-cross sectional area rating curve may be developed. On a monthly basis, data from the pressure transducers will be downloaded. With each download, a flow rate measurement will be recorded at each station using a hand held current meter. The approach to measuring flow velocity/rate will vary to accommodate location-specific conditions. Similar data from the New Jersey Sports and Exposition Authority outfall will be requested and used in the analysis, if available.

In addition, during the storm surge event monitoring (Task 1B.01 and 2A.03) a YSI multimeter will be deployed at each of the stations and programmed to record turbidity, pH, specific conductivity, DO, and temperature at a minimum of every 10 minutes. The meters will record data for up to 4 days or until it is evident that the complete storm hydrograph has been evaluated. A minimum of five measurements of flow rate will also be recorded at each station during each event using a hand held current meter. Concurrent with the flow measurements, a sample will be collected for analysis of TSS, TOC, and POC concentration. To the extent feasible, the flow measurements and sample collection will be from the center of the discharge at mid-depth.

Protocols for Task 1F are detailed in the project documents (QAPP/FSP/SOPs).

3.1.7 Task 1G – Sedflume (RI-P2-T1G)

Conceptual Basis and Rationale

As described in the CSM, multiple lines of evidence indicate that sediments within the BCSA are predominantly stable and that sediment resuspension does not occur to a great extent in the tidal portion of the study area. Preliminary analyses of the Phase 1 data are consistent with this understanding and indicate that the system velocities do not support net sediment erosion[1]. However, because resuspension is a potentially important mechanism by which sediments and associated COPCs can be mobilized, Task 1G includes Sedflume testing of sediment cores to further characterize the stability of the sediments at the BCSA. The direct measurement of sediment erosion rates via Sedflume provides a quantitative measurement of sediment stability that can be used to determine the potential for sediment mobility in a natural system (McNeil et al., 1996). During Task 1G, sediment cores collected from the BCSA will be analyzed on-site using Sedflume to measure erosion rates as a function of shear stress and depth. These data will be evaluated against measured system velocities and other Site data to evaluate the potential for sediment erosion within the BCSA.

Additionally, it has been demonstrated that erosion rates are strongly dependent on the bulk density of the sediments (Jepsen et. al, 1997; Roberts et. al, 1978). Because of this, the densities of the Sedflume cores will be determined by sub-sampling locations within each core so that the bulk density can be determined through wet/dry sample weight. Sediment particle size, sediment organic content, mineralogy, and gas content analyses will be performed at additional sub-sampled locations in the cores to provide further characterization of the sediments.

Scope of Work and Investigative Methods

Cores will be collected for Sedflume testing from twelve locations in the BCSA. Preliminary locations shown in Figure 3-5 were selected to provide good spatial resolution and a

[1] Erosion is defined here to generally mean the movement or transport of particulate from the bed of the waterway. It does imply a net loss of sediment over time as deposition processes may be balancing erosion.

representative characterization of sediment types and sediment bed morphology present in the system. The Sedflume testing is planned for the Spring 2011. Based on that timing, the location of the cores for Sedflume testing may be modified, in consultation with the USEPA, based on ongoing Phase 2 data collection efforts and analysis of the Phase 1 data. At each location, cores up to 60 cm long will be obtained in accordance with the methodology described in the FSP/SOP. Cores will immediately be visually inspected for length and quality. Sediments that show signs of disturbance from the coring process will be discarded and another core will be taken from that location.

A detailed description of Sedflume and its application are given in McNeil et al, 1996. The methodology for testing of the BCSA cores is detailed in the FSP. Sedflume is essentially a straight flume that has a test section with an open bottom through which a cross-section of the coring tube containing sediment can be inserted. Water is forced through the duct and the test section over the surface of the sediments. The shear produced by this flow causes the sediments to erode. As the sediments in the core erode, they are moved upwards by the operator so that the sediment-water interface remains level with the bottom of the test and inlet sections. Starting at a low shear stress, the flume is run sequentially at higher shear stresses until at least 2 to 3 mm of sediment are eroded from the core. This cycle is repeated until all of the sediment has eroded from the core. The result is a detailed quantification of the shear stress required to erode the sediment as a function of depth, and thus supports an understanding of sediment stability.

3.2 Task 2 – Surface Water Investigation

Surface water sampling is of particular importance in this RI/FS because it is the primary transport medium for COPCs (dissolved and absorbed to suspended sediments), it is a dominant point of contact of the bioavailable fraction of COPCs with many ecologically-relevant receptors, and most of the chemical-specific Applicable or Relevant and Appropriate Requirements (ARARs) are surface water standards. Trends in surface water concentrations may be a key consideration in setting the RAOs and scoping remedial alternatives.

The Phase 2 surface water sampling program will consist of two main components: 1) routine monitoring, and 2) Phase 2-specific monitoring. Routine monitoring consists of the same four subtasks as done in the Phase 1 program: a) Automated Sampling, b) Manual Sampling, c) Automated Storm Event Sampling, and d) Manual Storm Event Sampling. These tasks continue Phase 1 activities but incorporate Phase 1 observations through a refined and optimized monitoring network, including targeted sampling near some of the outfalls identified in Phase 1, and a focused analytical program. The second component, Phase 2-specific monitoring, consists of the following: a) a study of marsh-waterway interaction, b) sampling of marsh intertidal pools, c) a study of particulate COPC fractionation, and d) storm surge surface water sampling. The surface water program has been designed to address elements of Study Questions 1, 2, 4 to 7, 9, and 11 to 12; these questions consider stressors and their sources, sediment and chemical fate

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and transport, risk assessment, and remedy evaluation. This program is summarized in Table 3-3.

3.2.1 Task 2A – Routine Monitoring (RI-P2-T2)

3.2.1.1 Task 2A.01 Automated Sampling (RI-P2-T2A01)

Conceptual Basis and Rationale

Automated surface water sampling provides concentration data for the total COPCs present in surface water (i.e., including both particulate and dissolved fractions as one total value). Such surface water data serves two purposes:

- Mechanistic understanding. Data on the COPCs present in the BCSA components support a quantitative analysis of COPC exchange within the BCSA tidal system components while taking into account the upland tributary inputs and the flux with the Hackensack River. This is an extension of the hydrodynamic/sediment transport characterization described in Task 1.

- Risk characterization. Characterization of the total COPCs present in surface water has two benefits. First, it provides exposure point concentrations (EPCs) that will be useful for the risk assessments. Second, it supports identification of the primary COPCs by segment based on analysis of the relative probable risks.

As described in the chemical CSM, and as observed in Phase 1, most COPCs are predicted to primarily associate with the particulate phase. As a result, COPC concentrations may vary as a function of system energy, manifested as current velocities, because of these variables' effects on sediment deposition and resuspension. Because velocities will vary not only over a semidiurnal tidal period but also over a spring-neap cycle, it is necessary to capture representative, time-integrated concentrations that take both of these temporal sources of variability into consideration.

In the Automated Sampling Program (Task 2A.01), time-integrated samples will be collected using automated samplers. Composite samples will be collected to individually represent tidal flood and ebb conditions over a 2-week, spring-neap tidal cycle. The rationale for this sampling approach is the need to represent average chemistry conditions over a period long enough (i.e., a spring-neap tidal cycle) to capture the full range of hydrodynamic conditions observed at the Site. Moreover, by segregating samples into tidal flood and tidal ebb composites, it may be possible to assess differences between conditions representing influx from the Hackensack River (i.e., tidal flood) and conditions representing discharge from the BCSA headwaters and base flow (i.e., tidal ebb).

To maximize the collection of synoptic data, each of the two sampling events for Task 2A.01 will be performed in concert with other periodic sampling events, including Task 2A.02, Manual

Surface Water Sampling; Task 2B.01, Marsh-Waterway COPC/TSS Exchange; and Task 2B.02, Marsh Intertidal Pool Sampling.

Scope of Work and Investigative Methods

Automated samplers were installed during Phase 1 at five locations selected for long-term moored hydrodynamic monitoring as shown on Figure 3-6 and symbolized as "Routine Autosampler". Each sampler was programmed to collect aliquots approximately four times daily (i.e., at each tidal flood and ebb), with alternating contributions to the flood and ebb composite samples. The composite samples were retrieved from the samplers at the conclusion of the 2-week cycle and sent for laboratory analysis. This scope of work will be continued for Phase 2. Samples will be collected for two sampling events (one in the summer and one in the fall) from all five samplers. Samples will be analyzed as shown in Table 3-3. The analytical program shown in Table 3-3 focuses on metals and PCBs as the primary parameters of concern.

The timing of the 2-week, spring-neap cycle sampling will be determined based on weather conditions. The goal of the automated event program is to capture one relatively dry sampling event (i.e., time period characterized by a relatively extended period of dry weather) and one relatively wet sampling event (i.e., time period characterized by a relatively extended period of wet weather).

Phase 1 sampling was designed to target predicted two-week precipitation totals that were either below the 25th percentile or above the 75th percentile 2-week rainfall total (1.70 and 5.77 cm [0.67 and 2.27 in.], respectively). In practice, the weather forecasts were found to be unreliable in some cases; for example, a forecast of an upper-quartile event could in fact become a bottom-quartile event. Despite these challenges, the Phase 1 program did succeed in capturing events that were either considerably wet or considerably dry.

In light of i) the imprecision of weather forecasts and ii) the successful collection of data of considerably wet and dry events in Phase 1, the forecast constraints for Phase 2 will be relaxed compared to those of Phase 1. For Phase 2, the forecast target will be above and below the median 2-week rainfall of 3.38 cm (1.33 in) based on historical rainfall data from Jersey City, NJ provided by NOAA (2008). The objective of targeting more moderate events in Phase 2 is consistent with the overall RI/FS goal of evaluating the range of hydrodynamic conditions, as Phase 1 captured events towards the ends of the spectrum.

As each composite sample is collected over a 2-week period, the total rainfall over that period will be recorded. As the second collection event nears, 10-day weather forecasts will be reviewed, and a sampling period will be targeted that represents weather conditions that are most likely to be different from that of the previous event. The autosampler intake depth will correspond to that of the moored hydrodynamic/water quality station.

In Phase 1, samplers at stations MHS-01 and MHS-06 (BCC and Paterson Plank Road, respectively) were installed to correspond to the shallow YSI intake (two YSIs were installed at these stations). For Phase 2, the ISCO intakes will be shifted to correspond to the deep YSI horizon. The reason for this is the preference to monitor the deep horizon during storm surge events (Tasks 2A.03 and 2B.04), in which COPCs may be more elevated at the deeper horizons as a result of a temporary increase in the mass of suspended sediments. For the purposes of this task (2A.01), for which routine well-mixed conditions are expected to prevail, the intake shift is not expected to affect the sample nature.

3.2.1.2 Task 2A.02 – Manual Sampling (RI-P2-T2A02)

Conceptual Basis and Rationale

Manual surface water sampling has certain advantages over automated sampling; the most significant of these are as follows:

- While total metals data (Task 2A.01) serve as EPCs to some receptors, dissolved metals data are useful to refine the understanding of biouptake. For example, correlating mercury or methyl mercury in biota data with surface water mercury/methyl mercury is more valid if the surface water data represent the dissolved, as opposed to the total, fraction. Unlike automated sampling, manual surface water sampling allows field sample filtration to obtain dissolved-fraction data.

- The automated sampling program provides five data locations. By including a larger number of manual sampling locations, a more spatially detailed depiction of surface water conditions and concentration gradients from any one sampling event can be obtained.

The manual sampling subtask is a companion to the automated sampling subtask described in Section 3.2.1. A total of 37 locations are proposed for manual sampling (Figures 3-6 and 3-7). The locations are selected to achieve the following goals: i) complement the automated sampling locations to improve spatial resolution in the primary waterways, ii) characterize surface water conditions in tidal tributaries, and iii) characterize surface water loading from tributaries above the head of tide.

To maximize the collection of synoptic data, each of the two sampling events for Task 2A.02 will be performed in concert with other periodic sampling events, including Task 2A.01, Automated Surface Water Sampling; Task 2B.01, Marsh-Waterway COPC/TSS Exchange; and Task 2B.02, Marsh Intertidal Pool Sampling.

Scope of Work and Investigative Methods

The 37 locations have been modified from those of Phase 1 by re-allocating 14 of the Phase 1 locations to different areas of the Site based on Phase 1 findings associated with COPC

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distributions and potential sources to the BCSA (specifically outfalls). These re-allocations can be summarized as follows:

- The 14 Phase 1 locations that have been re-allocated were found to have relatively low COPC concentrations and/or concentrations consistent with neighboring locations (i.e., they were spatially redundant). Re-allocated locations were from BCC, LBC, the riser ditches, Ackerman's Creek, and Peach Island Creek.
- As shown in Figure 3-6 and 3-7, the 14 manual locations described above were re-allocated to address various data gaps, including i) sediment data-driven areas of interest, ii) outfalls identified in Phase 1, and iii) tributaries that were not previously sampled. These include the following:
  - Fish Creek, north of the Rutherford Landfill haul road, in an area where elevated COPC concentrations were observed in sediment;
  - a western tributary to LBC (Chubb Ditch) where multiple outfalls were observed;
  - three tributaries in Rutherford (Rutherford Ditches 1, 2, and 3), near the junction of LBC and Berry's Creek, where new tide gates have been installed;
  - three locations in MBC, near several outfalls;
  - three locations in the UBC main stem, where additional outfalls were observed; and
  - three locations in PIC and Eight Day Swamp tributary, where outfalls and elevated COPC concentrations in sediment were variously observed.

Two sampling events will be performed (summer and fall). Samples will be collected within a 2-week sampling period. It will not be feasible to collect all manual samples in one sample event at the same phase of the tidal cycle (semidiurnal or biweekly); hence, during the two events, collection sequences will be modified to capture a range of tidal period positions for a given location. Specifically, all manual sampling will be performed on days within a spring-neap cycle of moderate tidal range (i.e., neither spring nor neap tide). This method will control for varying tidal prisms and system energies. In addition, over the course of sampling, each manual sampling location will be sampled once during flood tide and once during ebb tide. The analytical program will focus on COPCs, but full analytical suite analysis will be completed for 10 to 20 percent of samples, as shown in Table 3-3. Samples will be field-filtered to support both total and filtered metals and PCB analyses.

The depth of sampling for all manual surface water samples will be 0.6 x the water depth below the water surface. According to Buchanan and Somers (1969) and Rantz et al. (1982), when water depths are less than 2.5 feet, the mean velocity within a given vertical profile of a stream cross-section is observed at 60% of the water depth. H.B.N. Hynes (1970) also concurs with these authors analysis. Rantz et al. (1982) also state that under conditions such as changing water depths (which occurs during sampling in the BCSA), the 60% depth method is appropriate for estimating the mean velocity at any particular vertical profile along a waterway. Therefore, the approach of sampling at the 60% depth (0.6 x the water depth at the sample location) will be applied universally as the approximate point of the mean velocity in the water column, consistent with the scientific literature. In light of the well-mixed hydrodynamic conditions as documented in Phase 1, this approach is appropriate for collection of representative surface water samples in the BCSA.

3.2.1.3 Task 2A.03 – Automated Storm Event Sampling (RI-P2-T2A03)

Conceptual Basis and Rationale

Storm event sampling will again be conducted to gain further understanding of the extent to which storms cause short-term stressor loading to the system. The storm event program will entail two components i) automated sampling, described in this section, and ii) manual sampling, described in Section 3.2.1.4 (Task 2A.04).

The effect of storms on the physical and chemical processes in the BCSA is an important component of a comprehensive mechanistic understanding of system dynamics, as well as risk assessment. The purely hydrodynamic and field parameter (e.g., temperature, salinity) aspects of water quality during storms will be addressed through the continuous hydrodynamic and transect monitoring of Task 1. However, the effect of storms on COPC concentrations is the subject of Tasks 2A.03 and 2A.04.

The relevant effects of storms on COPC concentrations can be summarized as follows:

- Storms can effect changes in COPC concentrations through hydrodynamic changes, even without consideration of COPC fluxes to the system. For example, a major precipitation storm event over the BCSA will increase the freshwater flow to the BCSA and to the Hackensack River. At the same time, a storm event may generate higher tides and salinity in the Hackensack River, which could propagate into the BCSA and increase salinity in the BCSA.

- Storms can also affect COPC concentrations by increasing the influx of COPCs to the system via increased runoff, increased point discharge activity, or through a tidal surge from the Hackensack River.

- Storms can result in increased water flux and thus energy in the system. As a result, there is increased potential for sediment re-suspension.

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The influence of COPCs in stormwater runoff on detected concentrations in surface water will vary throughout the watershed. Time-integrated sampling provides the most representative characterization of stormwater runoff effects on COPC presence. Moreover, the relatively short flushing times of the system suggest that any stormwater runoff effects on COPC presence will be very short-lived. Hence, it is necessary to have automated sampling equipment available to begin sampling on demand through cellular modem triggering.

The average tidal flushing time for the BCSA is estimated to be approximately 15 hours, although it is increased for neap tides and decreased for spring tides. This timescale can be used as a basis to define a period in which storm effects could be predicted to be manifested as elevated COPC concentrations associated with stormwater flush. Automated sampling allows a nearly instantaneous response to storm events through cellular phone activation of the samplers. It also has the advantage of improving field safety by reducing the need for manual sample collection during storm events.

In Phase 2, the storm monitoring network will be expanded to include several tributaries. Based on a review of COPC data and potential sources to the BCSA (including outfalls), many tributaries were identified as potential BCSA sources of COPCs into the tidal waterways and marshes. Storm events may increase the degree of COPC loading to the BCSA via tributaries through multiple mechanisms, including i) increased outfall discharges, ii) increased overland flow from upland areas, and iii) resuspension of COPC-bearing sediments in tributaries.

It is not practical to characterize storm-related effects in all tributaries, but this scope of work does include the addition of automated samplers in five tributaries which are closest to areas of generalized COPC impacts to Site media.

Scope of Work and Investigative Methods

In the automated sampling program, the five automated samplers deployed to perform Task 2A.01 (Section 3.2.1.1) as well as five new samplers deployed in tributaries will be used for short-term composite samples. The storm events will fall into one of two categories: (i) general storm events, defined as rain events with a predicted total rainfall that exceeds a target value as defined below, and (ii) storm surge events, in which a tidal surge occurs, stemming from coastal storms that generate higher tides and high wind events in Newark Bay and the Hackensack River. The two different types of storm events will be monitored separately, as follows:

- During a general storm event, the samplers will collect aliquots every 5 hours for composite analysis. A total of four aliquots covering a total period of 15 hours (the estimated average tidal residence time) will be collected. The analytical program will be the same as that employed for the automated sampling program (Task 2A.01) shown in Table 3-3. The threshold that will be applied to select a storm will be 2.5 cm (1 in.), which is the 97th percentile of daily total rainfall in Jersey City (i.e., 11 such storms per year are typical). The

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storm sampling events will be selected based on NOAA precipitation forecasts. Sampling will not begin until precipitation has begun on site. If the start of the storm is missed, the sampling frequency will be compressed such that sampling ceases 15 hours from the beginning of the rainfall.

- During a storm surge event, precipitation will not be the trigger for sampling for the waterway stations. Instead, onset of tidal surge and tidal recession will be the trigger. During the tidal surge, i.e., when tides rise substantially above predicted tides due to wind associated with a coastal storm, the samplers will be started and will sample approximately every three hours for four aliquots (nine hours total). Note that this will be modified during the rising limb as needed, i.e., sampling will cease early if winds subside early. Similarly, a second composite sample will be collected from each waterway station during tidal recession. If tributary samplers are used during the surge event (see below), their scheduling will be rain-driven, i.e., it will adhere to the 15-hour schedule described above for the general storm program.

Overall, four storm sampling events are planned. Two of the storm events will include testing in the waterways, and all four storm events will include testing in the tributaries during the Phase 2 program. If possible, the two full-network storm sampling events (i.e., events using all five waterway and all five tributary ISCO samplers) will be reserved for the storm surge events described in Task 1B.01 and Task 2B.04. At least one full-network event will be held in reserve for a surge event. However, given the uncertainty in the occurrence of storm surges, it is possible that by the time the first surge event occurs, several non-surge storms will have previously occurred. If, when the first surge occurs, three storm events have already occurred (of which one was sampled with the full network and two were sampled with the tributary stations only), then the remaining full-network event will be performed. In the event that Phase 2 concludes without any surge events, and the other three storm events have been expended on general storms, a fourth general storm event will be sought as promptly as possible. However, it may occur that Phase 2 will conclude as such, with only three automated storm events completed and no surge events observed.

The five tributaries for which new sampler locations have been selected include the following:

- Ackerman's Creek,
- Peach Island Creek,
- Eight Day Swamp Tributary,
- Nevertouch Creek, and
- South Ditch.

Whereas the five existing automated samplers in waterways were installed on pilings, the five new automated sampling locations will be installed in tributaries using simpler installations (light scaffolds in marshes) due to reduced waterway accessibility and the proximity of marsh or upland areas to the sampling points. Installation details are provided in the FSP.

The locations of all automated samplers for storm work (both existing and new) are shown in Figures 3-6 and 3-7.

3.2.1.4 Task 2A.04 – Manual Storm Event Sampling (RI-P1-T2A04)

Conceptual Basis and Rationale

Automated sampling provides composite consistency, responsiveness, and efficiency at the expense of spatial coverage and field and analytical method flexibility. Hence, it is desirable to gather a snapshot of stormwater data over a broader spatial array than that afforded by automated samplers to understand the variability introduced by system reaches, tributaries, etc. At the same time, it is also desirable to gather a more robust suite of analytical parameters and achieve rapid sample preservation.

During one of the two automated storm sampling events described in Section 3.2.1.3, a field team will be mobilized to manually collect water samples. While this subtask does not have the compositing or the rapid response available with the automated program, it has the advantage of allowing i) greater spatial coverage (20 locations), ii) a broader analytical program, and iii) the capability for sample filtering for dissolved metals analysis.

Scope of Work and Investigative Methods

Twenty of the 37 discrete sampling locations described in Section 3.1.2.1.1 will be manually sampled during the selected storm event. Figures 3-6 and 3-7 indicate which of the 37 locations are selected for manual sampling. The analytical program will focus on COPCs, but full analytical suite analysis will be completed for 10 to 20 percent of samples, as shown in Table 3-3. Samples will be field-filtered to support both total and filtered metals and PCBs analyses.

Due to the logistical constraints associated with mobilizing a field team for sample collection, a qualifying storm event will entail one with a forecast of sufficient probability to reasonably ensure a significant storm event. For this program, a qualifying storm will entail one for which the previous day's forecast predicts at least a 2.5 cm (1 in.) storm, which is the same rule as that of the automated stormwater program.

3.2.2 Task 2B – Phase 2 Specific Monitoring (RI-P2-T2B)

3.2.2.1 Task 2B.01 Marsh-Waterway COPC/Suspended Sediment Exchange (RI-P2-T2B01)

Conceptual Basis and Rationale

Phase 1 sediment sampling data show that several metals, including chromium, cadmium, mercury and methyl mercury, manganese, and zinc are present at higher concentrations in marsh sediments than in waterway sediments. These data suggest that marshes may represent an important sink for COPCs in the BCSA. As a result, several subtasks in the Phase 2 program are focused on the study of the potential for COPC exchange between the marshes and waterways.

Evaluating the potential for marsh-waterway COPC/suspended sediment exchange requires a detailed understanding of the mechanisms of water and sediment exchange between marshes and waterways. The Phase 1 investigation has indicated considerable variability in the morphology of marshes and the resultant interaction between marshes and tributaries. Rather than flooding through uniform sheet flow from the waterways onto the marsh plain, a network of primary, secondary, tertiary, and even higher-order tributaries appear to exchange water between the primary waterways and marsh plains. Many such tributaries cannot be readily seen in aerial photographs and are only observable during on-site reconnaissance.

Additionally, long-term marsh transducer measurements have shown the varying degrees of marsh inundation. During spring tides, marsh plains can flood by one foot or more, albeit for a relatively short duration (roughly four hours per high tide). During neap tides, marshes rarely flood, and if they do, it is for a shorter duration and a flood height measured in inches.

Based on these findings, it appears that sampling inflow and outflow water in the higher-order marsh tributaries, as close to marsh core locations as possible, is the most feasible means of sampling marsh-waterway exchange. The alternative approach, sampling marsh flood-ebb on the marsh plain, appears to offer limited opportunities for success and would require significant attention to properly time the sampling aliquots. Moreover, sampling marsh inflow and outflow should be performed using automated methods to avoid disturbance of sediment while sampling.

Given the challenges associated with sampling in marsh settings, it is appropriate to sample marsh-waterway exchange in several locations in one marsh to maximize a given dataset. For this reason, groupings of sampling locations have been designated in three marshes, of which two are in UBC and one is in MBC. These study segments have been selected because of their relatively higher COPC concentrations as compared to LBC and BCC.

To maximize the collection of synoptic data, each of the two sampling events for Task 2B.01 will be performed in concert with other periodic sampling events, including Task 2A.01, Automated Surface Water Sampling; Task 2A.02, Manual Sampling; and Task 2B.02, Marsh-Waterway COPC Exchange.

Scope of Work and Investigative Methods

Three marshes, Nevertouch Marsh, Eight Day Swamp, and Walden Swamp, have been selected for characterization of COPC/suspended sediment exchange between the marshes and waterways. The program will be closely associated with Task 2A.01, the existing automated sampling program. Each of the three marshes will have automated samplers installed in three locations for a total of nine stations (Figure 3-7). A two-week composite sampling program for influent and effluent composite samples will be completed in the summer and fall, on the same schedule as that of Task 2A.01. The analytical program will focus on COPCs, as shown in Table 3-3.

The three locations selected in each of the three marshes have variable configurations. In Walden Swamp, the three locations are all along one secondary tributary to evaluate the extent to which COPC flux changes with position in the marsh tributary. For Nevertouch Marsh and Eight Day Swamp, each marsh has two locations along one tributary to evaluate relative values and the third location on a separate tributary. Across the network of nine locations, a variety of tributary types have been selected, including naturally sinuous tributaries, straight-line mosquito ditches, and tributaries that lead to interior marsh intertidal pools.

Each automated sampler will be installed on the marsh plain next to each sampling point. A light scaffold will be installed on the marsh surface and the sampler will be secured on the base above Mean Higher High Water (MHHW) to avoid flood interference. Sample tubing will run from the sampler to the tributary, where a simple, pre-fabricated metal brace pushed into the tributary sediment will control the sample intake position. Reconnaissance of system behavior in advance of sampling will determine the appropriate sample intake placement to maximize water accessibility while minimizing entrainment of excess sediment.

Note that three TSS samples will be required for each station over the course of two weeks due to the limited hold time for TSS. Each sample will be run for a period of four or five days to accommodate the 7-day hold time.

3.2.2.2 Task 2B.02 Marsh Intertidal Pool Sampling

Conceptual Basis and Rationale

A component of Phase 2 concerns evaluation of the multiple potential components of COPC exchange between the marshes and waterways. In Phase 2, this potential for exchange will be examined through several subtasks among the Hydrology/Hydrodynamics, Surface Water, Sediment, and Groundwater/Surface Water Interaction tasks.

Task 2B.01 above will rely on sampling of water in higher-order marsh tributaries for its evaluation. It is also desirable to understand the nature of water on the marsh plain for the purposes of comparison since surface water does migrate across the marsh plains depending upon tides. Intertidal pools are selected for sampling due to their low ground elevation and resulting likelihood to remain flooded during low tide when the marsh surface is not inundated. Given the potential for unique geochemical characteristics, such as high organic carbon, different temperatures, etc. of marsh intertidal pool water, which could affect metals speciation, the collection of grab samples from these features will support the evaluation of the range of COPC and geochemical conditions of marsh surface water.

To maximize the collection of synoptic data, each of the two sampling events for Task 2B.02 will be performed in concert with other periodic sampling events, including Task 2A.01, Automated Surface Water Sampling; Task 2A.02, Manual Sampling; and Task 2B.01, Marsh/Waterway COPC/TSS Exchange.

Scope of Work and Investigative Methods

Figures 3-6 and 3-7 show the locations of 6 intertidal pool locations in BCSA marshes. Two locations are in Walden Swamp, and one location is in Nevertouch Marsh, Eight Day Swamp, Ackerman's Creek, and Tollgate Marsh, respectively. The samples from intertidal pools will be collected in the summer and fall during Phase 2. The analytical program will focus on COPCs as shown in Table 3-3. The sampling procedures for the manual sampling program (Task 2A.02) will be followed for this scope of work.

3.2.2.3 Task 2B.03 Particulate COPC Fractionation (RI-P2-T2B03)

Conceptual Basis and Rationale

Experience gained from both sediment megasites as well as urban stormwater management projects has underscored the importance of suspended sediment particle size with respect to COPC transport in the suspended phase. The affinity of COPCs for different particle sizes will depend upon the particle composition, which can consist of silica-based material for coarser fractions or clay minerals for finer fractions. Additional matrices are possible: in the case of BCSA suspended loads, analysis of the LISST data has indicated that coarser fractions likely consist primarily of organic material such as detritus or algae. These varying matrices will exhibit different mechanisms for sorbing COPCs; these mechanisms will in turn vary as a function of the COPC in question.

For the purposes of the RI, understanding particle-bound COPC flux is an important component of evaluating net sediment and COPC transport, including exchange with the Hackensack River and the marshes. If particle size distributions are found to vary between influent and effluent conditions or among differing hydrodynamic events, then understanding particulate COPC fractionation (i.e., the distribution of particle-bound COPCs as a function of particle size) will be an important component of understanding net baseline COPC exchange or predicted COPC exchange in extreme weather events. Similarly, if remedies that are considered as part of the FS may entail significant hydrodynamic modifications that could alter suspended particle size distribution, then particulate COPC fractionation may warrant consideration as a predictive tool during the FS.

Scope of Work and Investigative Methods

In this subtask, COPC fractionation in system waterways will be evaluated using filtration methods. Aliquots of homogenized (bulk) samples will be individually filtered through one specific pore size to identify the COPC division between fine (mud; silt and clay) and coarse (sand size) particulates.

COPCs of greatest interest for fractionation include TAL metals, PCBs, mercury, and methyl mercury, as shown in Table 3-3. Based on a review of available filter products and in consideration of compatibility constraints, two different filtration strategies will be used: i) nylon filters for metals (including mercury and methyl mercury), and ii) Teflon or stainless steel filters for PCBs.

The selected filter pore sizes have been chosen based on Phase 1 observations. The LISST data show that much of the particulate matter is present in either the 10 μm or 100 μm size ranges. A review of LISST data guided selection of filters with pore sizes that allow a reasonably equitable distribution of suspended sediments between the two major size fractions. The following approximate filter pore sizes have been selected:

- For metals, the filter pore sizes will be 60 μm.
- For PCBs, the filter size will be 51 μm.

The differences in filter sizes between analytical groups stem from differing filter availability from the manufacturers for metals and organic fractions.

COPC fractionation will be performed in three BCSA locations (one each in UBC, MBC, and BCC), with two sampling events each: one in warm weather, and one in cold weather. Unpreserved sample aliquots will be collected and submitted to the analytical laboratory for filtration and analysis within 24 hours. For each event, separate samples will be collected at (i) mid-flood and (ii) high slack tide to explore the potential for temporal differences brought about by different system velocities at different points in the tidal cycle.

3.2.2.4 Task 2B.04 Storm Surge Manual Surface Water Sampling (RI-P2-T2B04)

Conceptual Basis and Rationale

As described in Section 3.1.2 (Task 1B), the hydrodynamic transecting program for Phase 2 will be focused on two storm surge events in which energy inputs to the system, stemming from coastal storm wind-driven tidal surge and upland inputs, are predicted to be maximized. Conditions during these low-frequency, high-energy events will be compared with the typical range of monthly tides.

The rationale for Task 1B primarily discusses the predicted exchange of water and sediment during storm surge events. COPCs also tend to be associated with suspended sediment as observed in Phase 1 surface water results. Short-term, net COPC exchange stemming from storm surge events may result from one or more of the following mechanisms: (i) atypically high tides from Newark Bay and the Hackensack River that enter the BCSA during the surge, thereby entraining sediment and associated COPC loads; (ii) differences in suspended sediment compositions (e.g., grain size and organic fraction) among its sources (Hackensack River, marsh production/exchange, upland sources, and resuspended sediments), and (iii) atypical loads of COPCs from system tributaries. Hence, as with water flow and suspended sediments, the potential for COPC exchange that is not normally observed in more typical, lower energy conditions warrants consideration. In Task 2B.04, the hydrodynamic and suspended sediment exchange monitoring performed as described in Task 1B will be augmented with sampling for COPCs and additional, associated TSS measurements. Compared to other surface water events, the program is designed to provide considerable spatial discretization at a given monitoring station in both the horizontal and vertical aspects as well as temporal discretization. The additional TSS measurements serve two purposes: (i) augment Task 1B with TSS data collected in additional time steps, and (ii) support direct comparisons between TSS and COPC concentrations at any sampling point or time step desired.

The COPC/TSS sampling program described herein is designed to mirror that of the hydrodynamic transecting and TSS sample collection planned for Task 1B; however, the spatial density and temporal frequency of analytical sample collection in this task will be reduced from those of the TSS sample collection in Task 1B due to the increased logistical and analytical requirements associated COPC characterization.

Scope of Work and Investigative Methods

During the transect monitoring to be performed per Task 1B as described above, a second sampling vessel will work independently of the hydrodynamics vessel and be dedicated to COPC and TSS sample collection. COPC and TSS samples will be collected according to the following program:

- At the MHS-01 station (BCC), COPC/TSS samples will be collected at 3 locations and 2 depths each (6 X-Z stations total), in a configuration that corresponds directly to the sampling configuration for TSS sampling in Task 1B.

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- At the MHS-06 station (southern UBC, near Paterson Plank Road), COPC/TSS samples will be collected in 2 locations and 2 depths each (4 X-Z stations total). The lateral locations of the stations will be approximately 1/3 and 2/3 across the creek.

- COPC/TSS samples will be collected at a lower frequency than the Task 1B TSS samples due to the more complicated sampling logistics. A total of up to four sample sets for each of the rising and falling limb is planned.

- As with Task 1B, storm surge COPC/TSS sampling will be performed for two storm surge events in Phase 2.

- Also as with Task 1B, the sampling scope, locations, timing, and frequency are targets that are subject to logistical and safety-related constraints. Inclement weather or nightfall during key surge periods may reduce sampling productivity or preclude sampling altogether.

3.3 Task 3 – Sediment Investigation

The characterization of the distribution of COPCs horizontally and vertically in sediments in the BCSA was begun in Phase 1, with an emphasis on extensive BAZ characterization in the main channel of Berry's Creek, with more focused BAZ characterization in the tidal tributaries. Additionally, Phase 1 included a focused coring program that emphasized detailed geochronology; and, a limited marsh characterization program. As a result of the Phase 1 program, the distribution of COPCs in the BAZ is well-characterized, and an understanding of sediment deposition throughout the study area waterways has been developed. In the marshes, initial characterization of COPC distribution in surface and intermediate sediments is now reasonably well understood.

Phase 2 has been designed primarily to 1) expand the waterway coring dataset through a more extensive network of low-resolution coring locations targeting the zones of greatest COPC concentration variability, 2) supplement the Phase 1 characterization through a limited scope of BAZ sampling to fill data gaps and focus on potential source areas, 3) conduct a surface sediment investigation for correlation to biota COPC residues, 4) expand the marsh sediment dataset both laterally and vertically, 5) conduct a series of *Phragmites* plant material sampling, and 6) perform a focused set of high-resolution waterway cores to examine patterns of recent natural recovery in detail. Consequently, a combination of shallow and deeper sediment sampling is proposed in Phase 2.

In a manner similar to that of the surface water program, the sediment program addresses Study Questions 1, 2, 4 to 7, and 9 to 12; these questions consider stressors and their sources, sediment and chemical fate and transport, risk aspects, and remedy aspects. This program is summarized in Table 3-4.

3.3.1 Task 3A – Low-Resolution Waterway Sediment Core Sampling (RI-P2-T3A)

Conceptual Basis and Rationale

The BCSA bathymetric survey performed in accordance with the SAWP revealed three distinct sediment bedforms (i.e., mudflats, subtidal shallow, and deep [pool] areas) and transitions among bedforms that have implications for both the current distribution of COPCs in the BAZ as well as the historical deposition of COPCs in deeper horizons.

Overall, the Phase 1 coring program has demonstrated net deposition in the majority of locations, stability of sediments below the top few centimeters, peak COPC concentrations in the subsurface, and relative consistency in COPC concentrations greater than 50 cm. Based on these findings, the goals of the Phase 2 low-resolution waterway sediment coring program entails the characterization of a broader lateral distribution of sediments, encompassing both i) primary waterway bedforms that are under-characterized as well as ii) tributaries, for which the Phase 1 characterization was limited to the BAZ. For Phase 2, characterization in the top 60 cm (2 ft) is sufficient based on the relative consistency in deeper concentrations (i.e., concentrations gradients at depth stabilize) that has been observed to date.

Scope of Work and Investigative Methods

In Task 3A, sediment samples will be collected at 31 locations (Figures 3-8 and 3-9) from 0 to 60 cm, 3 samples each with the distribution as follows:

- UBC – 19 Locations,
- MBC – 9 Locations,
- LBC – 2 Locations,
- BCC – 1 Location.

Sufficient cores will be collected to meet sample volume requirements; the number of cores will be a function of recovery and moisture content and will be minimized to the extent possible. Samples for COPCs will be collected in the BAZ[2], BAZ bottom to 30 cm, and 30 to 60 cm intervals.

The analytical program will focus on COPCs, but full analytical suite analysis will be completed for eight samples, as shown in Table 3-4 and Figures 3-8 and 3-9. Geotechnical testing will be conducted on 13 samples to support FS analysis. Column settling tests will be conducted on five

[2] BAZ is defined as 0-10 cm in LBC, BCC, and MBC and 0-6 cm in UBC.

of the 13 geotechnical samples. Cores will be collected using vibracore methods, although a piston core may be employed in locations with limited access.

Sampling intervals will be modified to suit abrupt changes in lithology. Specifically, if the Holocene/Pleistocene sediment contact is encountered within one sample interval, sample depths will be modified to avoid one sample spanning both horizons, which could lead to spurious results. Additionally, due to difficulties with vibracore advancement in to Pleistocene sediments, and the limited potential of contamination in the Pleistocene sediments, only one sample in the Pleistocene clay will be collected.

3.3.2 Task 3B – Supplementary BAZ Sediment Sampling (RI-P2-T3B)

Conceptual Basis and Rationale

The presence of COPCs in the BAZ is of interest for the RI/FS because of the potential bioavailability of such COPCs to the aquatic food web. In particular, mummichog fiddler crabs and blue crabs play an important role in the aquatic food chain, feed in the BAZ and therefore may be exposed to COPCs present in this horizon. In addition, COPCs present in the BAZ may become periodically re-suspended.

BAZ sampling in Phase 1 consisted of 121 locations allocated spatially to represent the many sediment habitats and study segments present in the BCSA, plus an additional 80 locations in the transect/core program that were placed to focus on changes brought about by transitions among sediment bedforms. The Phase 1 BAZ program successfully characterized the lateral distribution of COPCs in the main channel of Berry's Creek and the primary tributaries. The distributions were, in general, found to show considerable lateral consistency, with variability in concentration largely brought about by BCSA-wide concentration gradients as opposed to localized variability. The cases in which sediment bedforms played an evident role in sediment COPC concentrations were limited to UBC and, to a lesser extent, MBC, in which deep pool samples had lower concentrations than those of intertidal mudflat samples. This is readily explained based on the lithologic and hydrodynamic CSM.

Overall, the need for supplementary BAZ sampling is limited to i) characterization of secondary tributaries that were not addressed in Phase 1, ii) sampling in the immediate vicinity of outfalls identified in Phase 1, and iii) step-out sampling at a limited number of locations in which elevated COPC concentrations were observed.

Scope of Work and Investigative Methods

Task 3B entails the collection of BAZ samples in 37 locations shown in Figures 3-8 and 3-9. The locations and rationale can be summarized as follows:

- seven locations in LBC and Oritani Marsh, mostly in Fish Creek and its tributaries, placed to better characterize the distribution of metals in the vicinity of Phase 1 samples where elevated concentrations were observed in Fish Creek;
- five samples in the complex of ditches in Rutherford north of the junction of LBC and BCC;
- four samples in southern MBC in the vicinity of observed outfalls and some Phase 1 samples with elevated COPC concentrations;
- twelve samples in central MBC, including the MBC main channel, a western tributary, Ackermans Creek, and Walden Swamp, placed to address observed outfalls and observed elevated concentrations in Phase 1 samples in the waterway and marsh; and
- nine samples in UBC, including eight samples located in small tributaries (Stiletto Ditch, Paterson Plank Ditch, North Ditch, upper Peach Island Creek, and tributaries of Eight Day Swamp Creek) and one sample placed in the vicinity of outfalls identified during Phase 1.

BAZ samples will be collected using box coring methods if the location is accessible by a large sampling skiff. Hand collection methods will be utilized if access is limited. The BAZ depth horizons defined in Phase 1 (0 to 10 cm for LBC, BCC, and MBC and 0 to 6 cm for UBC) will be used in Phase 2. Task 3B will focus on COPCs, but full analytical suite analysis will be completed for nine samples, as shown in Table 3-4.

3.3.3 Task 3C – Sediment Surface Investigation for Correlation to Biota COPC Residues (RI-P2-T3C)

Conceptual Basis and Rationale

Characterization of the horizontal and vertical distribution of COPCs in the BCSA sediments was begun in Phase 1, with an emphasis on extensive BAZ characterization in waterway sediments. The BAZ was defined on the basis of the sediment profile imaging (SPI) and was set equal to the maximum sediment depth at which there was any evidence of biological activity in each of the four reaches of the BCSA. For each reach, the overall BAZ depth was defined largely based on the presence of feeding tubes for infaunal organisms (e.g., tubificid oligochaetes and capetellid polychaetes), which extended well below the sediment oxygen boundary defined by the redox potential discontinuity (RPD). For example, in UBC, the BAZ was defined as 6 cm but the RPD depth was 0.7 cm.

The data for primary COPCs in BAZ samples (i.e., mercury, methyl mercury, and PCBs) were used in the Phase 1 report along with COPC data for mummichog to examine the relationship between sediment and fish COPC concentrations. Mummichog were used in the evaluation due to their high spatial fidelity (i.e., range across small areas) that is greater than any of the other sampled species (i.e., white perch, blue crab). Consequently, mummichog are most likely to display a body burden to sediment relationship. Although the Phase 1 data did reveal a statistically significant and positive relationship between sediment and mummichog primary COPC levels, the overall correlation was weak (i.e., r^2 of ~0.3 and less). There could be a number of reasons for the lack of a strong correlation, including 1) too few data for sediment or fish to accurately capture variability, 2) lower spatial fidelity of mummichog than reported in the literature (i.e., they roam across a greater area, including the adjacent marsh areas during high tide periods), and 3) not accurately measuring the bioavailable fraction of COPCs in sediments to which mummichog prey are exposed.

As reported in the literature (Abraham 1985), mummichog are opportunistic feeders but have a diet that consists of many benthic and epibenthic species (e.g., copepods, amphipods, flies and other insects) that do not inhabit the anoxic portions of the sediment column. Additionally, mummichog behavioral activities involve disturbance of the aerobic portion of sediment surfaces to suspend sediment particles and expose lower trophic-level organisms for consumption. The data collected during the method development work prior to the Phase 1 sampling showed that COPC concentrations at depths of 2 cm (i.e., the oxygenated zone) were lower than concentrations at greater depths. Therefore, though the Phase 1 data sampled COPCs in the BAZ, it might not be representative of the concentrations to which mummichog and its primary prey are exposed.

The Phase 2 program will include additional investigation to better define the diet of mummichog in the BCSA (see section 3.1.5.4). In addition, a more targeted investigation of COPC concentrations in the shallow oxygenated zone of the sediment column will be conducted to potentially support a more precise understanding of correlations between COPC concentrations in sediment and mummichog. The proposed sediment sampling will occur in shallow, intertidal mudflats, where mummichog are most actively feeding.

Task 3C has been designed to i) establish a dataset of sediment parameters potentially relevant to mummichog COPC uptake, including select COPC concentrations and sediment physical-chemical properties, and ii) identify correlations between the collected sediment dataset and the mummichog COPC data at BCSA locations where minimum and maximum COPC sediment concentrations have been reported. In addition, the data analysis will take into account the COPC concentrations in the adjacent subtidal areas and marshes and the data from the evaluation of the exchange of COPCs between marshes and waterways. To meet these goals, shallow sediment sampling of intertidal, mudflat sediments within UBC and LBC will be performed which, to the extent practical, spatially and temporally overlap with mummichog collection activities outlined in Task 5A. If the data from this sampling support a better understanding of COPC residues in mummichog relative to sediment concentrations, additional sampling across all reaches may be conducted in Phase 3.

The sediment surface investigation consists of the following task: mud flat sampling of sediments to depths of observed RPD, and statistical analysis to discern correlations among sediment parameters and mummichog COPC concentrations. The sediment surface investigation, in concert with biota investigations and efforts described herein to establish correlations between the two, addresses Study Questions 1 to 7, and 9 to 12; these questions consider stressors and their sources, receptors, sediment and chemical fate and transport, risk aspects, and remedy aspects. Sediment data from this task will be compared against mummichog composite data obtained in Phase 2 Task 5A.

Scope of Work and Investigative Methods

In Task 3C, shallow sediment sampling will occur along intertidal mud flats co-located with mummichog sampling stations of LBC (20 locations) and UBC (20 locations) (see Figures 3-8 and 3-9). Sampling depth is 2.5 cm for all samples.

Samples will be collected as close as practically possible to mummichog collection stations; similarly, the timing of sediment samples will be such that sampling will be conducted as soon as practically possible following mummichog collection. Sediment sampling will be performed via either subaqueous box coring from a marine vessel or through direct hand sampling on exposed mud banks. Disturbance of benthic habitat via sediment sampling (temporary disruption of the RPD, suspension of sediment particles into the water column, and potential mixing of sediments above and below the RPD) should also be avoided prior to mummichog sampling. Care will be taken to obtain sediments samples from the desired intervals. Sufficient sediment will be collected to meet sample volume requirements; the number of box cores or hand sampling grabs will be a function of recovery and moisture content and will be minimized to the extent possible. Samples will be homogenized in decontaminated stainless steel bowls with stainless steel utensils. Ideally, all parameters will be tested out of one homogenized sample. However, analytical volume requirements and high moisture contents (which can adversely affect reporting limits) may lead to multiple box core collections. Carefully developed volume requirements have been obtained from the analytical laboratories to promote the attainment of desired reporting limits while minimizing volume requirements. These refined volume requirements are discussed in the QAPP/FSP (QAPP Worksheet 19).

This program will focus on mercury, methyl mercury, and PCBs, as summarized in Table 3-4.

3.3.4 Task 3D – Marsh Sediment Sampling (RI-P2-T3D)

Conceptual Basis and Rationale

The *Phragmites* marshes constitute the majority of the footprint of the BCSA tidal areas; they are present adjacent to the primary waterways in all four study segments. They support ecological receptors of interest, including avian and mammalian receptors as discussed in Section 4. Due to tidal flooding, exchange of sediment and COPCs between the primary waterways and marshes is predicted.

During Phase 1, marsh sediment sampling was performed in 24 locations in existing marsh transects, with samples collected in two intervals (0 to 5 cm and 10 to 15 cm). The shallow interval was selected to represent the marsh surface, whereas the intermediate interval (10 to 15 cm) was selected to mimic the interval reported in Weis et al. (2005) in which peak metals concentrations were observed in Eight Day Swamp marsh sediments. Most COPC concentrations were markedly lower in the BAZ than in the 10 to 15 cm horizon, with the notable exception of manganese.

The Phase 1 program was intended to be limited in spatial extent and geared towards assisting the Group with the scoping of the Phase 2 marsh program. It provided the following important insights that have been used in the development of the scope presented in this Phase 2 Work Plan addendum:

- The distinct differences in concentrations between the BAZ and intermediate horizons, indicate that the selected intervals are well placed to characterize i) concentrations that are relevant from the standpoint of direct contact exposure and ii) concentrations that may be relevant in an interflow transport scenario.
- The general consistency in concentrations across a given transect and interval suggest relative homogeneity of marsh sediment concentrations and the stability of marsh sediments.
- Typical root mat depths averaged 67 cm to the bottom of large roots and 76 cm to the bottom of fibrous roots.
- Based on the findings of the Phase 1 marsh investigation, the objectives of the Phase 2 marsh program include the following:
- Provide broader spatial coverage of COPC characterization in the 0 to 5 and 10 to 15 cm horizon, i.e., in locations outside existing marsh transects;
- Provide some characterization of marsh sediment concentrations at greater depth, including sampling horizons that are deeper than the intervals characterized by Weis et al. (2005);
- Provide geochronology in a subset of deeper locations to assign sediment dates to COPC data from various horizons; and
- Assess the mercury methylation/demethylation dynamics both vertically and horizontally in the marsh sediments.

An important component of Task 3D entails geochronological dating marsh sediments using selected isotopes found in recent history in the atmospheric background. The radiological markers utilized in Phase 1 were specific isotopes of cesium and lead (^{137}Cs and ^{210}Pb). Overall, these two radioisotopes provide different lines of evidence to depict the geochronology of a sediment core: ^{137}Cs is the best indicator for a specific date (1963), whereas ^{210}Pb provides a more continuous picture of deposition timing.

- ^{137}Cs was generated during nuclear weapons testing in the 20th century, beginning in the 1950s and reaching its peak in 1963. Hence, the sediment sample with the peak ^{137}Cs concentration may be reasonably inferred to represent the horizon deposited during this time period. ^{137}Cs has a half-life of 30.23 years, so it is relatively stable.
- ^{210}Pb is generated in the atmosphere through the decomposition of radon gas. Upon decomposition to ^{210}Pb, it settles into sediments and water bodies via atmospheric deposition. With a half-life of 22.3 years, a measurable decrease in ^{210}Pb presence occurs in cases in which steady sediment deposition occurs over the course of decades.

Scope of Work and Investigative Methods

> Assuming a conservatively high sedimentation rate of 0.5 cm/y, the 50 cm horizon would represent sediments from 1910, well before the period of chemical-intensive industrialization.

Phase 2 marsh sediment sampling will be performed in a total of 78 locations, as shown in Figures 3-8 and 3-9. Sampling locations have been more broadly distributed throughout the marshes than the transect-focused samples in Phase 1 to provide a more spatially representative characterization of COPC concentrations. Three marsh sampling programs will be done and each are described below.

42 locations: 0 – 15 cm cores, 2 sample intervals, COPC assessment

These 42 locations will be sampled in the 0 to 5 cm (~ 2 in) and 10 to 15 cm (3.9 to 6 in) sampling horizons based on the demonstrated value of these two horizons in meeting two different characterization objectives (near surface exposure-point concentrations and higher, historical concentrations at depth to develop the understanding of fate and transport potential).

12 locations: 0 – 50 cm cores, COPCs, geochronology (10 of 12)

These 12 locations will be sampled in the 0 to 50 cm (19.6 in) horizon, with four samples collected per location in the 0 to 5 cm, 10 to 15 cm, 15 to 25 cm, and 35 to 50 cm horizons. The two deeper horizons have been selected based on likely sediment age. Weis et al., (2005) found that marsh sediment accretion rates of 0.33 to 0.5 cm/y were occurring in Eight Day Swamp. Assuming a conservatively high sedimentation rate of 0.5 cm/y, the 50 cm horizon would represent sediments from the early 1900's. In ten of these deeper sampling locations, geochronology will be performed in the top 38 cm. Twelve samples from each of the cores will be tested for ^{137}Cs and ^{210}Pb radioisotopes (0 to 30 cm on 3 cm centers, then 30 to 38 cm on 4 cm centers). Given the stability of the marsh setting, geochronology is not deemed necessary to evaluate sediment stability; instead, it will be performed in five locations to better characterize the sediment accumulation rates associated with differing COPC concentrations. This information will also be useful to assess natural recovery rates.

24 locations: 0 – 16 cm, high resolution cores, sectioned in 2 cm horizons

These 24 locations will be utilized to assess mercury methylation/demethylation dynamics. Methyl mercury concentrations were elevated in the 0 to 5 cm and 10 to 15 cm intervals in the Phase 1 sampling. This targeted study will focus on UBC and MBC, as methyl mercury concentrations are highest in these study reaches based on Phase 1 data; however, cores will also be collected in LBC and BCC to confirm if similar processes are occurring across the range of observed concentrations. A total of 24 cores are proposed: 12 cores in UBC (six each in Nevertouch Marsh and Eight Day Swamp), six cores in MBC (Walden Swamp), three cores in LBC, and three cores in BCC. Sediment cores will be co-located with cores for the complete COPC list (metals, PCBs), as well as the well clusters proposed in UBC and MBC for marsh interflow studies.

Sediment cores will be collected to a depth of 16 cm (approximately 6 inches) below the marsh surface. This depth includes the interval where metals typically are highest in concentration and is a reasonable interval to evaluate as most biological productivity (i.e., most biomass) occurs in this horizon. Upon retrieval, the cores will be sectioned in 2 cm intervals. Sediment redox and pH measurements will be collected from each 2 cm interval immediately upon sectioning by inserting the redox/pH probe (e.g., Orion 250A or similar) directly into the sediment. Three measurements will be collected along a horizontal transect across the face of the core for each depth interval to ascertain the degree of variability in redox and pH both vertically and horizontally.

Sediment samples will also be collected from each 2 cm interval for total and methyl mercury analysis. Ancillary parameters for analysis will include AVS/SEM, pH, sulfide, sulfate, and TOC. In addition, salinity will be measured in the water at the bottom of the core before backfilling the sediment core location. Data from these high resolution cores will be used to support an analysis of factors controlling mercury methylation/demethylation in BCSA marshes, and evaluate potential controls on methylation in the FS.

In addition to the analyses of mercury, methyl mercury, sulfate/sulfide, AVS/SEM, and redox in the high-resolution marsh sediments, leach-based analyses of marsh sediments will be performed for biodegradable organic carbon (BDOC) (Table 3-4). Methylation in marsh sediments requires suppressed redox conditions; Compeau and Bartha (1984) suggest that redox levels of -220 mV are necessary for methylation to occur. It is predicted that ongoing biodegradation of labile organic carbon may be responsible for driving marsh sediments to reducing conditions. Bianchi (2007) discusses the nature of dissolved organic carbon in estuaries, most notably from the standpoint of lability vs. refractory characteristics and how these may relate to molecular size, age, and source. A relatively streamlined approach to assessing BDOC is laboratory testing of sediment leachate (derived from a sediment extraction method using deionized water) for dissolved organic carbon over a period of 5, 10, and 15 days. The concentration of DOC and rate of decay of DOC provides an indication of i) the source magnitude of DOC from the marsh sediments and ii) the lability of the DOC. BDOC analyses will be performed for four horizons from 6 high-resolution cores. Variability in the DOC will be evaluated in each core and between locations to better understand horizontal and vertical distribution of BDOC sources and the role played in altering the methylation/demethylation balance.

Geotechnical

- 13 Root Mat samples will be collected and analyzed for Moisture content and grain size by hydrometer and sieve
- 5 Below Root Mat samples will be collected and analyzed for:
    - Atterberg Limits
    - Moisture content
    - Field vane shear testing
    - Loss on ignition (LOI)
    - Grain size by hydrometer and sieve

Marsh sampling will be performed using methods described in the FSP and SOPs. Protocols will be as specified in the project documents. The analytical program will be performed as shown in Table 3-4.

3.3.5 Task 3E – *Phragmites* Sampling

Conceptual Basis and Rationale

As an additional component of investigating the exposure point concentrations and potential exchange of COPCs between the waterways and marshes, Task 3E will include sampling of *Phragmites* material from ten locations (in Eight Day Swamp, Walden Swamp, Ackerman's Marsh, and Berry's Creek Marsh) to assess the following.

The following samples will be collected to evaluate potential exposure point concentrations in marsh invertebrate/insect habitats.

- ***Phragmites* Leaves:** Leaves from living plants will be collected

- **Marsh Surface:** Recently dead coarse plant material will be collected from the base of the plants.

- **Detritus Layer:** The detritus layer just above the root zone sediments will be collected.

The following samples will be collected to evaluate potential exposure point concentrations for mammals in the marsh system.

- ***Phragmites* Roots:** The root layer will be sampled.

This analysis will focus on COPCs as shown in Table 3-4. In addition, the leaves from living and dead plants and detritus layer will also be analyzed for stable isotopes to trace the carbon, nitrogen, and sulfur significance through the food web. (A comprehensive summary of the stable isotope study, including the proposed analysis of *Phragmites* samples is described in Task 5D.)

Scope of Work and Investigative Methods

In Phase 2, four types of *Phragmites* samples will be collected at ten stations (three in each of UBC and LBC and four from MBC). Locations are shown in Figures 3-8 and 3-9. The analytical program for Task 3D is shown in Table 3-4.

In addition to the 40 samples for COPC plant tissue residue analysis, samples of live leaves, marsh surface material (e.g., dead leaves), and detritus will be collected for stable isotope analysis. Three samples of each type will be collected in each of the three BCSA study segments (LBC, MBC, UBC) for a total of 27 samples.

3.3.6 Task 3F – Waterway High-Resolution Sediment Core Sampling

Conceptual Basis and Rationale

As discussed in several project documents, multiple lines of evidence evaluated to date support the CSM of a net depositional hydrodynamic framework for the BCSA. Lines of evidence to support this conceptualization have been presented in documents associated with both the SAWP and RI/FS.

In Task 3F, the BCSA Group will revisit areas of identified sediment deposition from Phase 1 to perform high-resolution sediment coring and analyses for COPCs and geochronology. The objectives of this task include the following:

- Refine the understanding of sediment age through greater vertical sampling precision. This will afford a more accurate understanding of key geochronological milestones (e.g., the 1954 and 1963 horizon and peak, respectively, for ^{137}Cs);

- Refine estimates of sediment deposition rates;

- Evaluate, on a finer vertical scale than was available in Phase 1, the extent to which COPCs (mercury and PCBs) attenuate in fine layers toward the sediment mudline;

- In addition to informing the overall CSM of sediment deposition and COPC presence, it will also support the evaluation of sediment resuspension potential in the shallowest horizons through time-sequenced concentration gradients that reflect past changes that may relate to resuspension events.

The Phase 1 sediment coring program, a low-resolution program, consisted of 27 cores advanced to 1 m, with COPCs tested in five sampling intervals and geochronological parameters (^{137}Cs and ^{210}Pb tested in 10 cm intervals to 1 m and ^{7}Be tested in 2 cm intervals to 6 cm). The program accomplished several objectives, including (i) confirmation of depositional conditions in the clear majority of locations, with an estimated 91% majority of the BCSA waterways classified as depositional; and (ii) depiction of coherent trends of COPC profiles with depth as a function of study segment and depositional status in many areas.

Whereas the Phase 1 program entailed numerous locations at low sampling resolution, the Phase 2 program will include a more limited number of locations sampled at a high resolution. The Phase 2 coring program will complement the Phase 1 program by beginning with the broad, general patterns depicted with lateral detail in Phase 1 and subjecting the resulting CSM to a high degree of vertical refinement in select locations.

Scope of Work and Investigative Methods

In Task 3F, seven high-resolution sediment cores will be advanced for COPCs and geochronology. Sampling methods and analyses will be performed as follows:

- The cores will be advanced to 2 m below the mudline, although the core will be terminated if Pleistocene sediments are encountered first. Initially, only the top 1 m will undergo laboratory analysis for geochronology and COPCs. The 1 to 2 m section will be archived in the event that contingent analyses are desired as described further below.

- The top 1 m of sediment core will be subsampled on 2 cm horizons. In general, only alternating subsamples in the 0 to 1 m interval will be submitted for analysis, with some exceptions. All intervals in the 0 to 12 cm horizon (i.e., 0 to 2 cm, 2 to 4 cm, 4 to 6 cm, 6 to 8 cm, 8 to 10 cm, and 10 to 12 cm) will be analyzed. At depths greater than 12 cm, however,

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alternating samples will be submitted. Specifically, samples corresponding to 12 to 14 cm, 16 to 18 cm, 20 to 22 cm, etc., will be archived, whereas samples corresponding to 14 to 16 cm, 18 to 20 cm, 22 to 24 cm, etc., continuing to the final interval of 98 to 100 cm will be submitted for analysis.

- Analyses will include selected COPCs (mercury, methyl mercury [0 to 20 cm horizon only] and PCB Aroclors), geochronology radioisotopes (^{137}Cs and ^{210}Pb throughout; ^{7}Be in the 0 to 6 cm horizon), and focused geotechnical parameters (streamlined grain size/loss on ignition) to support radioisotope data interpretation.

Archived samples will be analyzed as needed under the following scenarios:

- The 0 to 1 m sampling interval fails to capture the ^{137}Cs peak corresponding to the year 1963, and knowledge of this peak depth is necessary for adequate core interpretation; in this scenario, selected subsamples from the 1 to 2 m horizon core will be tested;
- Scatter or imprecision in the ^{137}Cs and/or ^{210}Pb dataset hinders interpretation; or
- Erratic COPC distributions warrant additional analyses to clarify core interpretation.

The sampling method will be as follows:

- Due to significant sample volume constraints, a box corer (Gray-Ohara or similar) will be used for sampling top layers; the box corer will be used to the greatest depth that is feasible and that avoids sample deformation (box core sampling may be feasible up to 50 cm below the mudline in some cases.)
- A 4 in. diameter vibracore will be advanced for the collection of deeper aliquots. The vibracore will be outfitted with an external frame to allow a perpendicular entry into the sediment bed. The vibracore head will be outfitted with a check valve to allow easy release of overlying water during sediment penetration while reducing potential for sediment slumping or winnowing during retrieval.

Additional details are provided in the FSP and Standard Operating Procedure (SOP) 3.2, Appendix C of the Phase 2 QAPP/FSP Addendum (Geosyntec/Integral, 2010, submitted concurrently with this Work Plan).

The rationale for coring to 2 m as an ultimate depth is based on the findings of the Phase 1 coring program. Provided that long-term deposition rates are 2.5 cm/y or less (virtually all of the estimated deposition rates from Phase 1 were below this amount), a 2 m core will capture about an 80-year period. The program as designed will provide detailed data related to sediment stability over that period.

In the ideal case, all parameters out of a given horizon will be tested out of one core, which will allow for the greatest confidence in correlations between COPCs and ancillary parameters such as radionuclides and geotechnical parameters. However, analytical volume requirements, limited sample recoveries, and high moisture contents (which can adversely affect reporting limits) may lead to a requirement for additional cores to meet volume requirements. Based on the findings of the methods development work, volume requirements have been obtained from the analytical laboratories to promote the attainment of desired reporting limits while avoiding the collection of unnecessary sample volume. These refined volume requirements are discussed in the QAPP/FSP. However, in the event that two or more cores are required, high-priority analytical parameters (e.g., radioisotopes, mercury, PCBs) have been selected to indicate groups that most warrant concurrent collection from the same core to support the most realistic evaluation of correlations. These high-priority parameters include COPCs that are expected to be most significant with respect to BCSA-specific sources and parameters that inform the geochronology and biogeochemical processes that may affect these parameters (e.g., radionuclides). The QAPP/FSP shows this prioritization (See FSP page 4-2). Core samples will be processed in descending order, from shallowest to deepest sample, to minimize premature core disturbance during processing.

The seven high-resolution coring locations are shown on Figures 3-8 and 3-9. The core locations are based on the following:

- High-resolution cores have been designated in the vicinity of existing, Phase 1 low-resolution geochronology cores. It is desirable to select locations in which the general behavior (e.g. depositional vs. no net change, and approximate deposition rates) is reasonably well understood. While there is some redundancy inherent in this approach, the goal of Task 3F is not to perform the broad, generalized geochronology performed in Phase 1; its purpose is to provide detailed characterization in locations in which the general behavior is already understood.

- The high-resolution coring locations have been selected in areas with extensive sediment deposition overlying the Pleistocene lake deposit. As noted above, the coring is not being performed to identify areas of deposition; it is intended to refine the understanding of the deposition over time as one line of evidence in understanding the sediment stability in waterways.

- The coring locations have been selected to represent all four study segments as well as a mix of sediment bedforms (mudflats and subtidal areas).

- Coring locations have been selected to avoid localized sources of hydrodynamic disturbance, e.g., tributary junctions or outfalls, to avoid confounding results in the COPC or radioisotope distributions.

- The goal of the coring program is to characterize up to 2 m of Holocene sediments; however, in areas that are otherwise desirable for characterization but which may lack 2 m of sediments, the coring will characterize the thinner horizon of Holocene sediments as available.

The Phase 1 results are presented in Appendix O of the Phase 1 Site Characterization Report (Geosyntec/Integral, 2010). The seven locations correspond to existing Phase 1 geochronology locations and are described as follows:

- A core in LBC near Phase 1 location TBZ-117. This location is high on a mudflat on the west bank of central LBC. Estimated deposition rates are roughly 2 cm/y. Low-resolution COPC sampling in Phase 1 indicated low COPC concentrations and relatively little gradient in COPC concentrations with depth, with a slight decline towards the surface.

- A subtidal core in central BCC near Phase 1 location TBZ-134. As with the LBC location, estimated deposition rates are relatively high (>1.7 cm/y). Similar to the LBC location, low-resolution COPC sampling in Phase 1 indicated low and relatively consistent COPC concentrations, with a slight decline towards the surface. This location will be moved northwest of the TBZ-134 to avoid confounding effects from the tributary from Tollgate Marsh.

- A mudflat core in southern MBC near Phase 1 location TBZ-140. In Phase 1, this location showed a typical ^{137}Cs peak at a depth of 65 cm. COPC concentrations gradually increase with depth.

- A mudflat location in central MBC just east of the TBZ-149 location. TBZ-149 showed a shallow ^{137}Cs peak and low rates of deposition (approximately 0.36 cm/y). It is predicted that moving this location to the mudflat to the east, adjacent to Walden Swamp, will capture a location with a more pronounced record of deposition and COPC attenuation.

- A UBC mudflat location near Lower Peach Island Creek location TBZ-170. In Phase 1, this location showed deposition rates of approximately 1 to 1.5 cm/y and more notable attenuation rates for COPCs than observed farther to the south.

- An intertidal northern UBC location near Phase 1 location TBZ-178 near the East Riser Ditch tide gate. A deposition rate of roughly 1 cm/y was consistently calculated from the Phase 1 data collected at this location using several methods. Low-resolution COPC samples showed gradual declines toward the surface.

- A mudflat area in UBC that was previously an oxbow channel near Nevertouch Creek and the West Riser Ditch tide gate. Elevated COPC concentrations are known to be present and relatively low velocity profiles are likely to have lead to a detailed profile of sediment and

COPC deposition. This core will be advanced nearby the Phase 1 core TBZ-184, from which a sediment deposition rate of 0.55 cm/y was estimated.

3.4 Task 4 – Groundwater/Surface Water Interactions

Task 4 of the Phase 2 investigation includes evaluation of interflow from the marshes and characterization of groundwater discharge from landfills in LBC. The groundwater program has been designed to address Study Questions 1, 2, 4 to 7, 9, 11 and 12; these questions consider stressors and their sources, chemical fate and transport, risk aspects, and remedy aspects.

3.4.1 Task 4A Marsh Interflow Characterization

Conceptual Basis and Rationale

The groundwater desktop study (Appendix D of the Phase 1 Report; Geosyntec/Integral, 2010) demonstrates that groundwater discharge flux to the BCSA is small relative to tidal flux rates. Further, the study found that discharge rates of interflow from the marshes to the BCSA waterways are small relative to groundwater discharge from upland and landfill areas. However, the Phase 1 investigation found that the marsh sediments contain elevated concentrations of COPCs. The marsh sediments contain high organic carbon concentrations (i.e., approximately 20 percent) and support a reduced redox environment that favors formation of insoluble mineral phases for many of the metals COPCs. Under these conditions, the COPCs are predicted to strongly partition to the sediment phase and thus be highly immobile. The Phase 2 investigation will evaluate select BCSA marshes to determine if interflow discharge of COPC mass from the marshes to the BCSA waterways and tributaries is a significant COPC transport pathway. The Phase 2 investigation will include installation of wells in select marsh locations to evaluate the marsh hydrologic properties, aqueous COPC concentrations, and other parameters to assess the potential for COPC migration from the marshes to the BCSA waterways/tributaries via the interflow pathway.

Scope of Work and Investigative Methods

The marsh interflow characterization program will include installation of three sets of well clusters in each of Walden Swamp, Nevertouch Marsh, and Eight Day Swamp, i.e., nine clusters total (Figure 3-10). The well clusters are located in the vicinity of existing marsh transects and associated piezometers, and, in most cases, are co-located with the Phase 2 marsh tributary sampling program that is designed to assess exchange between the marshes and the BCSA waterways/tributaries (Section 3.1.2). Each set of well clusters will include wells installed at two depth intervals, 15 to 46 cm (0.5 to 1.5 ft) and 46 to 91 cm (1.5 to 3 ft). The marsh wells will be installed manually in boreholes dug using a hand auger. The wells will be constructed with 0.5 feet of 2-inch inner-diameter (ID), 10-slot PVC well screen and sufficient riser to extend the wells approximately 4 feet above ground level. Number 1 Morie sand or equivalent will be emplaced in the wells annulus surrounding the well screen and a minimum 0.5 foot bentonite plug will be installed above the filter pack. Following installation, each well will be developed, and its horizontal and vertical coordinates will be surveyed. Hydraulic conductivity will be evaluated in each well through falling-head slug tests.

The wells will be sampled in the summer and fall of 2010 and sample analysis will focus on COPCs, as shown in Table 3-5. This sampling will be completed with low-flow sampling methods within the two-week period when the automated surface water sampling takes place (Task 2; Section 3.1.2). Care will be taken to ensure the pore water is not oxygenated in the process of sampling or storage for transportation to the laboratory for analysis, using standard ground water sampling procedures. Prior to sampling, the wells will be purged and general water quality parameters (pH, specific conductivity/salinity, ORP, DO, and temperature) recorded. During the periods intervening the sampling, pressure transducers will be installed in each well. Water levels in the wells and the adjacent marsh transect piezometers will be recorded to collect detailed water level elevation data to establish lateral and vertical hydraulic gradients.

The well gauging and sampling results will be evaluated to identify hydraulic and concentration gradients. Interflow estimates will be evaluated in the context of the estimated tidal prism associated with the marsh in question. Concentration data will be evaluated with respect to nearby surface water data and flow quantities to assess its significance with respect to other potential sources of COPCs.

Protocols regarding well installation and construction, well development, sampling collection, IDW management, and slug testing are detailed in SOPs provided in the project documents, as amended for Phase 2. These protocols conform to NJDEP's Alternative Ground Water Sampling Techniques Guide (NJDEP, 1994), the NJDEP Field Sampling Procedures Manual (NJDEP, 2005), and the regulations regarding well construction and decommissioning in the Subsurface and Percolating Water Act (N.J.S.A. 58:4A-4.1 et seq.) and associated regulations (N.J.A.C. 7:9D-1.1 et seq.).

3.4.2 Task 4B Focused Sampling of Groundwater Discharge

Conceptual Basis and Rationale

The landfill areas in LBC are predicted to support relatively high rates of groundwater flux to the BCSA waterways due to the higher permeability of the landfill waste materials. Further, localized areas may exist where BCSA bank sediments have little to no thickness and thus have limited capacity to attenuate COPCs prior to discharge to the BCSA waterways. The Phase 1 data suggest that the concentrations of secondary COPCs are somewhat elevated in the Fish Creek area and in portions of the main LBC waterway adjacent to the landfills. These data suggest that groundwater discharge from the LBC landfills may represent a localized source of these chemicals. To address this potential, the Phase 2 investigation will include the installation of wells in the vicinity of Fish Creek and in other selected locations in LBC to quantify the local groundwater and COPC flux from the landfills to the BCSA waterways.

Scope of Work and Investigative Methods

The landfill groundwater program will include installation of one well at each of seven locations in LBC (Figure 3-11). Wells will be installed as conditions allow. If wells cannot be properly placed, then the objectives of this task may be achieved by other means. This may include 1) collection of groundwater well data from other entities including ENCAP, 2) sampling of existing wells within the ENCAP area, or 3) other such methods that may be determined. The use of such alternate means of data collection will be done in coordination with USEPA.

The wells will be installed (depth of approximately 2 to 3 feet) using hollow stem auger drilling methodology. The wells will be screened within the landfill waste material. The wells will be 2-inch ID wells, with a 4-inch annulus. Number 1 Morie sand or equivalent will be emplaced in the annulus surrounding the well screen and a minimum 0.5 foot bentonite plug will be installed above the filter pack. Following installation, each well will be developed and its horizontal and vertical coordinates surveyed. Hydraulic conductivity will be evaluated in each well through falling-head slug tests.

The wells will be sampled in the summer and fall of 2010 and samples will be analyzed for the full analyte list as shown in Table 3-5. Prior to sampling, the wells will be purged and general water quality parameters (pH, specific conductivity/salinity, ORP, DO, and temperature) recorded. During the periods intervening the two sampling events, pressure transducers will be installed in each well.

The landfill well data will be evaluated to understand the degree of hydraulic connection with the waterways. Transducer data in the wells will be compared to those of the waterway stations to establish hydraulic gradients between the landfill and waterway. COPC data in the wells will be evaluated in comparison to LBC surface water data and relative flows in the waste and waterways to evaluate the significance of the landfills as potential sources to LBC.

Protocols regarding well installation and construction, development, sampling collection, IDW management, and slug testing are detailed in the project documents, as amended for Phase 2. These protocols conform to the NJDEP Field Sampling Procedures Manual (NJDEP, 2005), and the regulations regarding well construction and decommissioning in the Subsurface and Percolating Water Act (N.J.S.A. 58:4A-4.1 et seq.) and associated regulations (N.J.A.C. 7:9D-1.1 et seq.).

Data from these wells will be analyzed in relation to data from upland monitoring wells and taken into account the changing conditions due to the ongoing landfill closure activities.

3.5 Task 5 – Biota Investigation and Human Activity Assessment

The Phase 2 sampling program will consist of: 1) biota collection for tissue residue analysis, 2) human use monitoring, 3) a fish community survey, 4) food web studies, 5) waterway benthic community survey, 6) marsh invertebrate/insect community survey, and 7) evaluation of marsh production, function and value.

These data will be used to refine the CSMs and address Study Questions. The objectives of the Phase 2 biological sampling program are to i) determine the presence and level of COPC accumulation in key components of the BCSA aquatic food web, ii) better characterize human use in the study area, iii) evaluate the overall structure and composition of the BCSA fish community compared to reference sites, and iv) better define BCSA food web structure to aid in a better understanding of chemical accumulation and biomagnifications. The biota investigation program corresponds to Study Questions 1, 3, 5, 7, 9, and 11 to 13; these questions consider stressors, receptors, chemical fate and transport, risk aspects, and remedy aspects.

3.5.1 Task 5A – COPC Residues in the BCSA Food Web

Conceptual Basis and Rationale

Biota are exposed to a range of conditions and COPCs in the BCSA. By measuring tissue concentrations of COPCs in a variety of mid- to upper-trophic level fauna with varying degrees of mobility, relative bioavailability and bioaccumulation will be directly measured across the range of conditions in the BCSA. Mercury, methyl mercury, and PCBs are the focus of the residue sampling program.

The target species for COPC residue collection during the Phase 2 program are mummichog, white perch, blue crab, and fiddler crab. COPC residue data in these species will help support both the baseline human health and ecological risk assessments and an understanding of COPC bioavailability and uptake. Each of these species is predicted to be an important potential prey source for ecological receptors or human anglers/crabbers. Additionally, data for mummichog and fiddler crab will support an evaluation of the quantitative relationship between measured sediment concentrations and biological tissue, given that both of these species exhibit a relatively high degree of spatial fidelity and therefore may be more reliably paired with sediment data to examine bioaccumulation relationships. An understanding of the relationship between COPC residues in sediments/surface water and biota will ultimately be very important for the evaluation of remedial alternatives in the FS.

The Phase 2 biota sampling efforts will focus on the main channels of Berry's Creek (UBC, MBC, LBC and BCC). The smaller waterways of Fish Creek, Ackerman's Creek, Peach Island Creek, and South Ditch also will be sampled, but only for mummichog. As discussed previously, the waterways to be sampled within the BCSA will be segmented according to hydrologic, bathymetric, and salinity data previously collected and compiled during the scoping study phase of this RI/FS. Biota sampling points will be co-located with surface water and BAZ sediment sampling locations to the extent practicable, and specifically, in UBC and LBC, with the 0 to 2.5 cm sediment samples being collected in those reaches. Biota residue sampling for Phase 2 will take place in mid to late summer. The COPC load in the biota tissues will be considered to be representative of both bioaccumulation and the exposure to a predator species.

Scope of Work and Investigative Methods

Table 3-6 summarizes the sample locations and analyses to be conducted for the residue evaluation in biota. Table 3-7 lists the proposed sampling areas and the number of samples proposed for each species per sampling location. All biota samples will be analyzed for total mercury, methyl mercury, PCBs, lipids and moisture content.

Mummichog

Due to their high ecological relevance throughout the BCSA, mummichog will be collected at 67 sampling locations (Table 3-7). The total number of samples in Phase 2 is comparable to Phase 1, with a few additional samples intended to fill spatial and/or COPC concentration gradient data gaps observed in Phase 1 (Figures 3-12 and 3-13). In addition, three individual samples from each BCSA reach will be collected for stable isotope analysis (Task 5D).

Minnow traps will be used; however, small seines or gill nets may also be used to supplement collection where habitat conditions are favorable. If minnow traps are used, they will be aligned parallel to the creek bank, with the opening facing the incoming tide. To ensure maximum catch, minnow traps will be left in place for a minimum of 5 hours. Approximately 10 to 30 adult ($\geq$50 mm [2 in.] total length [T_L]) male and female (combined) mummichog will be collected from each sample station in each segment of the BCSA during the sampling period. Mummichog samples will be whole-body composite samples.

Mummichog samples will be placed on ice in the field and returned to the holding facility. Individuals will be counted and examined externally with any visible morphological abnormalities noted. After this processing step, fish from each sampling location will be combined to produce one composite sample per location (for a total of 67 composite samples throughout the BCSA). To the extent practical, the same number of fish will be used to create each composite. In cases where inadequate mass is available, the following hierarchy will be used to determine the order in which analyses are to be performed: methyl mercury, mercury, PCBs, lipids and moisture content.

White Perch

White perch will be collected from 24 locations throughout BCSA (Table 3-7). The proposed total number of samples for white perch is increased above Phase 1 efforts. Residue data for this species will be important in the human health and ecological risk assessments and, therefore, additional data that can be used to support a better understanding of the magnitude and distribution of COPCs within the BCSA will be valuable. Approximately 8 to 16 adult (≥100 to 200 mm T_L [~ 4 to 8 in.], depending on availability) male and female white perch will be collected from each of six sampling stations within each of the four sampling segments using small otter trawls, and/or gill nets (Figures 3-12 and 3-13). Half of these will be processed for whole body analysis and half will be processed for fillet analysis. If insufficient numbers of fish are caught to support whole-body and fillet analysis, fillet analysis will be prioritized to support the human health risk assessment. In addition, three individual samples from each BCSA reach will be collected for stable isotope analysis (Task 5D).

White perch will be placed on ice in the field and returned to the holding facility. Individuals will be measured (T_L in mm) and weighed (g). In addition, all fish caught will be examined externally and any visible morphological abnormalities (e.g., tumors) will be noted. After this processing, individual fish from each sampling station will be composited to form two composite samples per location: one for whole body and one for fillet analysis (for a total of 24 whole-body composite and 24 fillet composite samples throughout the BCSA). Fillet samples will be processed in the laboratory as scales-off, skin-on. To the extent practical, the same number of fish will be used to create each composite.

Blue Crab

Blue crab will be collected from 24 locations throughout BCSA. The proposed total number of samples for blue crab is increased above Phase 1 efforts for the same reasons offered above for white perch. Three to five adult crabs (≥100 mm [3.9 in.] carapace widte [CW]; male and female) will be collected from the six sampling stations within each of the four segments (Figures 3-13 through 3-14). Blue crabs will be collected from the BCSA waterways using a standard baited (e.g., chicken or fish pieces) crab pot, seine nets, or trawls. Traps are the preferred method and will be placed in the creek on the rising incoming tide and allowed to remain in place for approximately 5 hours through the outgoing tide to maximize potential catch per unit effort. Traps will be checked frequently to minimize crab stress or mortality. If seines are used, seining will take place on the incoming tide and will continue until the minimum number of crabs are collected. Crabs will be removed from the traps or seine and segregated for sampling. Soft-shelled and sponge crabs will be returned to the creek. In addition, three individual samples from each BCSA reach will be collected for stable isotope analysis (Task 5D).

Blue crab samples will be placed on ice in the field and returned to the holding facility Individuals will be sexed, weighed (g), and measured (CW in mm). Additionally, any morphological abnormalities will be noted. After this initial processing, individual crabs from each sampling station will be composited to form one composite sample per location (for a total of 24 composite samples throughout the BCSA). At the laboratory, the samples will be processed by removing the edible muscle tissue (i.e., all leg and claw meat, back shell meat and body cavity meat) from the crab and the remaining carcass will be analyzed as well (for a total of 24 muscle samples and 24 carcass samples). In addition, for three of the six samples per segment, the hepatopancreas will be removed and analyzed separately (for a total of 12 composite hepatopancreas samples). The hepatopancreas is a food source for some crabbers and data show that chemical contaminants may concentrate in the hepatopancreas. Approximately 100 g (0.22 lb) of edible muscle tissue, the remaining carcass, and hepatopancreas will be collected for each composite sample. To the extent practical, the same number of crabs will be used to create the composite samples. In cases where inadequate mass is available, the following hierarchy will be used to determine the order in which analyses are to be performed: methyl mercury, mercury, PCBs, lipids and moisture content.

Fiddler Crab

Fiddler crabs were a target species during the Phase 1 COPC collection activities; however, unfavorable weather conditions precluded their collection. The Phase 2 effort will be moved to late summer which should increase the activity and therefore availability of fiddler crabs for sample collection. Three composite samples will be collected from each of the four segments of the creek for a total of 12 samples (Table 3-7). Fiddler crabs will be analyzed as whole body samples. In addition, three individual samples will be collected from each BCSA reach for stable isotope analysis (Task 5D).

Fiddler crabs will be hand collected from the creek banks and mudflats at low tide. Using a hand trowel, access to the fiddler crab burrow will be blocked and individuals will be captured and placed into 18.9 L (5-gallon) buckets with ice. Approximately 30 to 50 adult fiddler crabs (male and female) from each of three sampling stations within each segment (Figures 3-12 and 3-13) will be collected, to the extent practicable depending on the numbers available in each study segment.

Individuals will be sexed, measured (CW in mm) and weighed (g) and externally examined with any morphological abnormalities noted. After this processing, individual crabs from each sampling station within each segment will be composited to form one composite sample per location (for a total of 12 composite samples throughout the BCSA). To the extent practical, the same number of crabs will be used to create each composite. In cases where inadequate mass is available, the following hierarchy will be used to determine the order in which analyses are to be performed: methyl mercury, mercury, PCBs, lipids and moisture content.

3.5.2 Task 5B – Human Use Monitoring (RI-P2-T5B)

Conceptual Basis and Rationale

An understanding of the type, extent, frequency and duration of human use in the BCSA is important for evaluating potential human exposures and risks. Data collected during the Phase 1 study supported previous observations made during Site reconnaissance that human use of the

BCSA is infrequent and largely restricted to portions of the creek that are easily accessible, such as near roadways that cross the creek, or to areas that are accessible by boats near the Hackensack River. Additional data are needed to better characterize human use of the study area.

The Phase 2 efforts will be a continuation of the methods used in Phase 1 and consist of recording direct observations of human use by the field team during the sampling season and observations of human use recorded by digital cameras positioned at locations of documented human activity. These methods will be supplemented by informal interviews of recreational users and others that are observed in the BCSA.

Scope of Work and Investigative Methods

Direct Observation

Observations of human use will continue to be recorded by the field team during all times that the field team is mobilized. The field team will record observations of human activity in Berry's Creek, tributaries and the adjacent *Phragmites* marsh.

Direct observations of human use will be recorded manually on an observation log as used in Phase 1 (Figure 3-14). Information to be recorded includes the age and sex of the person observed, their location relative to the waterway, the type of activity occurring, and any other signs of human activity (e.g., crabbing equipment, watercraft). Informal interviews will be conducted on occasion to request information on specific activities (e.g., fishing, crabbing, catching bait fish) and catch disposition (e.g., release, retain to eat, use as bait).

Digital Camera Monitoring

Digital camera monitoring will be conducted at three of the four locations monitored in Phase 1 to document Site usage at discrete access points along the shoreline or via boat traffic into BCC (the LBC location observed during Phase 1 will not be sampled in Phase 2). The cameras used for the activity monitoring consist of three 4 megapixel weatherproof digital cameras. The three cameras will be placed in the same locations as during the Phase 1 camera study since each camera successfully captured human activity during Phase 1. A detailed description of each location is provided below:

- The Paterson Plank Road (PPR) camera is located on the south side of the Paterson Plank Road Bridge across Middle Berry's Creek (MBC) with a field of view encompassing the south-eastern bridge footing (727019 ft N, 608606 ft E). Field crew observations and Phase 1 photographic evidence indicate that the footing under the PPR Bridge is a location for crabbing and possibly fishing. The camera is placed to maximize the view under the bridge.

- The Route 3 camera is located on the east bank of BCC facing south with a field of view encompassing the north-eastern Route 3 bridge footing (720697 ft N, 605342 ft E). Field crews observed and cameras documented people bait fishing with minnow traps and fishing with rod and reel at this location.

- The BCC camera is located on the old bridge footing beside the MERI sampling station on the eastern shore of the canal with a field of view encompassing the BCC waterway from the bridge footing to the Route 3 bridge (717160 ft N, 608963 ft E). The camera is placed to maximize the length of waterway captured in the photograph. Field crews and the Phase 1 cameras observed some boats in BCC.

These locations will be moved if operational issues arise at a given location or if repeated vandalism occurs. Any camera that is moved will be placed in a monitoring location as comparable as possible to the Phase 1 monitoring location with respect to likely human use.

As occurred during Phase 1, photos will be taken at each location every 30 minutes during daylight hours. Photos from all cameras will be manually downloaded on a weekly or biweekly basis, and reviewed for human activity using photo-handling software (Adobe Photoshop Lightroom ®, Version 2). A Human Activity Photo Database for Phase 2 photos will be created to record the observations for any photo indicating human activity. These photos will be tagged in the database with identifiers indicating the camera name, number of individuals observed, sex, location of individuals, and activity. The photo database will be used to compile human activity statistics for each camera including: the frequency and relative proportion of various recreational activities (e.g., number of visits for fishing per week) and the frequency of human use per unit time (e.g., week, month, year). This approach will provide additional data to support a site-specific evaluation of potential human exposures in the BCSA.

3.5.3 Task 5C – Fish Community Survey (RI-P2-T5C)

Conceptual Basis and Rationale

The Phase 1 study of the BCSA aquatic community showed a diversity of fish species that are characteristic of the Hackensack River Meadowlands region. The Phase 1 program did not include any sampling of the fish community at reference sites, however, and therefore a comparison could not be made of community and population characteristics at the Site compared to similarly sampled fish communities at reference sites with comparable habitats. Fish are an important ecological receptor in the BCSA – they are integrators of chemical exposures from surface water, sediment, and diet, they form the prey base for certain species of wildlife, and they are the target of at least some recreational activity in the BCSA. Therefore, fish were selected as an assessment receptor in the BERA WP and the Phase 2 program includes additional study of the fish community.

Scope of Work and Investigative Methods

The fish community survey will be conducted in Berry's Creek and at the three reference sites in late July or August (see Section 3.1.6 for a discussion of the scope of work in reference areas). In Berry's Creek, the survey will focus on the main channel across the four BCSA segments: UBC, MBC, LBC, and BCC. As presented in the RI/FS Work Plan, these segments were defined based on similarities in salinity regime, similarities in water depth, and the presence and relative abundance of tidal mudflats.

The Phase 2 fish community survey will collect data that can be used to characterize and compare the fish communities of the BCSA and reference sites. The Phase 2 fish community survey will be conducted during the summer in the BCSA. A survey by NJMC (2005) in BCC showed the highest abundance and diversity in the fish community during the summer months, with decreases in both characteristics during other seasons. Similar findings occurred in the Phase 1 aquatic fauna field survey in the BCSA, with the highest abundance and highest average diversity recorded in the summer season.

The BCSA sampling segments reflect differences in salinity within the study area. Sampling will be performed in: each of the four individual BCSA segments (UBC, MBC, BCC, LBC), corresponding to the segment breakdowns previously used in the Phase 1 program. Based on the Phase 1 sampling stations, sampling areas have been established in the main channel of Berry's Creek and include a mixture of shallow and deeper pool habitats. Proximity to previous sampling locations will ensure that data from Phase 1 and Phase 2 can be appropriately aligned and interpreted. Generalized sample locations for the BCSA are depicted in Figures 3-12 and 3-13.

Due to distinct bathymetric differences among sampling areas within any given segment, different sampling techniques will be employed to characterize the fish community. Where water depths are suitable (i.e., BCC, LBC), otter trawls (approximately 3.7 m [12 ft] long) will be deployed. Using methods described in USEPA (2000) and NJMC (2005), each sampling station will be trawled twice for 3 minutes each time. This sampling method will also be utilized in deep pools located in sampling areas. If possible, four trawling stations will be sampled in each segment. In addition, three gill net stations will be selected in each segment, and one variable mesh gill net will be deployed for 24 hours at each station. If deep pools are present in a segment, at least one gill net station will be located in a deep pool. Twenty minnow traps will be baited and deployed in each segment for 24 hours. Minnow trap stations will be located along the shoreline of each segment at the interface of water and marsh vegetation.

Data will be logged for each sampling event at each sampling location. Qualified biologists with experience in fish surveys will identify and record all juvenile and adult fish collected using common reference guides. For white perch, the length of each individual will be recorded for length-frequency distribution analysis, which will be used to evaluate the population age structure among study segments, and to compare with reference area (Everhart and Youngs, 1975). Additionally, during each sampling event, the conventional water quality parameters (temperature, DO, and salinity) will be collected from surface water at an elevation off of the channel bottom of 0.6 to the depth at the time of measurement. Water quality parameter data will be collected prior to conducting any biotic sampling to minimize sediment disturbance prior to water sampling.

Data from this subtask will be compiled for quantitative analysis of community composition and comparison between BCSA and reference segments in the Phase 2 Report and as part of the BERA. Results will include an overall species list with common and scientific names and species counts for each site. Additional analyses of ecological indices describing fish community composition and structure including species richness, evenness, diversity, relative abundance, and a tabulation of data on general biological condition between sampling locations and within each segment will also be compiled. Text will also be provided discussing species' use of different habitats and relationship relative to segment location.

The data will be used to determine if fish community characteristics within the BCSA differ from those at regional reference sites. The fish community has been proposed as the assessment endpoint for the BERA. Multiple lines of evidence (e.g., COPC levels, physical stressors) will be used along with the community data to support evaluation of whether COPCs are the likely cause of any observed differences. The BERA WP provides additional discussion of how these data will be used and analyzed. In addition, fish tissue will be a component of the future Remedial Action Objective (RAOs). Therefore, understanding the BCSA fish community in relation to the reference areas as part of the baseline studies is valuable in establishing the overall health of the fish community in the BCSA and their use as a remedial metric and in the evaluation of short term and long term impacts in the risk analysis.

3.5.4 Task 5D – Food Web Study (RI-P2-T5D)

Conceptual Basis and Rationale

An aquatic food-web study will be conducted as part of the Phase 2 RI. Both mercury and PCBs are key COPCs in the BCSA and both chemicals bioaccumulate in organisms and typically biomagnify in aquatic food webs. The degree of biomagnification of chemicals such as mercury and PCBs is affected by the structure of aquatic food webs, including the arrangement of linkages among dominant species in the web and the number of trophic levels from the base of the web to a receptor of interest. The goal of the food web study is to document the trophic relationships of key fish and invertebrate species in the BCSA. The resulting data will be used to support the BERA and ultimately, the evaluation of remedial alternatives.

Differences in food web structure may influence mercury and PCB exposure pathways and ultimately determine the mercury and PCB content of upper trophic-level fish and wildlife species. Consequently, spatial variations in food web structure can lead to a heterogeneous distribution of risk among habitats and potentially different strategies for remediation. The short- and long-term effects of alternative remedial actions as well as natural recovery need to be evaluated in the context of variation in aquatic community structure and habitats within the BCSA. For these reasons, a study of the food web characteristics in the various BCSA reaches is valuable to the overall RI/FS process.

The food web study consists of two related investigations: 1) an analysis of prey and other food items in the gut contents of fishes to quantify composition of their diets, and 2) an analysis of stable isotope composition of selected components of the food web to assign trophic level and determine the ultimate source of energy for key receptors. The objectives of the food web study are listed below, with corresponding study component(s) that address each objective (in parentheses GCA=gut content analysis, SI = stable isotope analysis):

1. Identify key prey for mummichog and white perch to support evaluation of bioaccumulation (GCA).

2. Quantify relative diet composition of dominant fish species (as percent by mass) of food type in diet of each target fish species to support exposure analysis and identification of potential environmental compartment(s) for remediation (GCA).

3. Identifying key food resources and trophic linkages supporting dominant fish species to support analysis of exposure pathways, bioaccumulation modeling, and risk characterization in the BERA (SI, GCA).

4. Identify environmental media (e.g., sediments/detritus, water column particulates, water) and compartments (ditch/tributary, low marsh, high marsh) that are the primary sources of PCBs and mercury to the food web supporting dominant fish species (SI, GCA).

5. Support the development of a dynamic bioaccumulation model for PCBs and mercury if the need for such a model is indicated by analysis of statistical bioaccumulation models (SI, GCA).

Gut Content Analysis Scope of Work and Investigative Methods

Objectives 1 through 5 will be addressed by collecting and analyzing information on the gut contents of key receptor fish species within the BCSA and each of the three reference sites investigated in Phase 1 at the site and in reference areas (see Section 3.1.6 for reference site details). Two species will be targeted for collection based on their presence and relative abundance in the BCSA and/or their expected position in the food web. These species and the life stages targeted in the food web study are:

- Mummichog (*Fundulus heteroclitus*) – (primary and secondary level consumer) (adults)

- White Perch (*Morone americana*) – (secondary level consumer) (juveniles and adults)

Samples will be collected in July concurrent with the Phase 2 fish community study (Task 5C). Samples will be collected in all four segments of the BCSA (BCC, LBC, MBC, and UBC).

Fish gut content will be collected and analyzed from each sampled segment and for each target species (limited by the number of each species captured in each segment). A target of 20 fish per species per segment (with dietary items present in their stomachs) will be sent to the laboratory for usual gut content analysis. This number may be modified based on the number of fish, the size of the fish, and the percentage of fish with empty stomachs captured during the aquatic community survey. The planned process for sampling and analysis is:

- Fish stomachs will be removed in the field, and cut open to ensure they are not empty.

- Each gut will be individually packaged in a sample jar, labeled, and preserved.

- Gut contents in individual fish will be analyzed in the laboratory to enumerate and identify the fish's diet. Organisms in the gut contents will be identified to the Family level, with identification to lower taxonomic level as practical.

- In addition, one composite sample of the gut contents of each species in each segment will be analyzed for determination of dry mass of each of the three most abundant taxa in the gut. Dry mass data will allow quantification of the proportions of the diet comprised of each taxa.

The Phase 2 report will include an analysis and summary of these data. The report will describe the diet composition of mummichog and white perch in each segment of the BCSA and examines similarities or differences to the regional reference areas. The data will be used to support development of food web diagrams, assess spatial heterogeneity in food web structure, and support COPC exposure analysis in the BERA.

Stable Isotope Study Scope of Work and Investigative Methods

To address objectives 3 through 6 of the food web study, a stable isotope analysis ($\delta^{15}N$, $\delta^{13}C$, and $\delta^{34}S$) of major potential components of the aquatic food web of the BCSA will be conducted. These components include:

<u>Primary Producers and Detritus</u>

- Reed grass (*Phragmites australis*, standing live and dead)

- Marsh detritus layer (just above the root zone)

- Benthic microalgae in intertidal mudflats

- Suspended organic matter/phytoplankton

Aquatic Invertebrates:

- Blue crab (*Callinectes sapidus* (adult [> 100 mm CW]))
- Mud crabs (*Rithrapanopeus harrissi*)
- Fiddler crab (*Uca minax*)
- Amphipods (e.g., *Orchestia grillus*, *Gammarus tigrinus*)
- Shrimp (e.g., *Palaemonetes pugio*)
- Benthic infauna (species to-be-determined at the time of the Phase 2 benthic community survey, but likely will include tubificid oligochaetes and Capatellid oligochates)

Fish:

- Mummichog – (primary and secondary level consumer) (adults)
- White Perch (secondary level consumer) (juvenile [<90 mm] and adult [≥90 mm])

Each of the food web components described above will be collected (as possible) in sufficient amounts to comprise triplicate samples for stable isotope analysis ($\delta^{15}N$, $\delta^{13}C$, and $\delta^{34}S$) for each of the four segments of the BCSA (BCC, LBC, MBC and UBC). White perch will be collected at two distinct life stages in each segment to the extent possible: white perch juveniles and adults consume different diets (Neuman et al., 2004) and based on the Phase 1 Aquatic Fauna Survey results, they may be present in the BCSA in different distributions or durations.

Collections will occur in mid to late summer 2010[3] concurrent with biota tissue sampling. Fish and invertebrates will be collected during the Phase 2 COPC residue study proposed for the BCSA (Section 3.1.5.1, Task 5A), using the 12 stations defined for perch/mummichog/fiddler crab/blue crab sampling (Figures 3-12 and 3-13). Fish, blue crab, and fiddler crab are already targeted for sampling during that study and will be collected concurrent with samples collected for COPC analysis. Mud crab, amphipods, and shrimp have been regularly collected in the past as by-catch using the methods planned for COPC residue study, so the same methods planned for the COPC residue study will be used for collection of these additional invertebrate species.

[3] Seasonal shifts in isotopic signatures, resulting primarily from seasonal physiological changes in primary producers that alter relative rates of isotope uptake, are well established in the literature; however, capturing seasonal variability in isotopic relationships is beyond the scope of this particular study and is recognized as a source of uncertainty for understanding year-round trophic relationships

Fish and adult blue crab will be collected and placed on ice for transport to the lab. At the laboratory, muscle tissue will be extracted for isotope analysis from fish and adult blue crab. Smaller invertebrates, including mud crab, hermit crab, shrimp, and amphipods will be collected, weighed to ensure a composite sample with adequate mass for analysis[4], placed on ice for transport to the laboratory, and then homogenized and subsampled for isotope analysis. For these smaller invertebrates, a low-Molarity acid wash followed by whole-body homogenization will be used to prepare samples for isotope analysis. Marsh detritus and samples of live and dead standing *Phragmites* will also be collected during the *Phragmites* sampling effort (Task 3E).

Settling plates (ceramic tiles) will be used to collect benthic microalgae because they serve as surfaces for natural colonization of the algae and because this method minimizes contamination from sediment and non-algal materials relative to direct sampling of the marsh surface. Ceramic tiles will be set on the marsh surface at low tide and fastened into place with rebar. Tiles will be allowed to colonize for a period of approximately 30 days, after which they will be retrieved and algae will be scraped from the tiles and used for isotope analysis. It is unknown how natural sedimentation and colonization rates in this system may affect the success of this method, so benthic microalgae may additionally be collected directly from marsh surfaces. A fraction of the sample scraped from the tiles in each reach will be preserved with Lugol's solution and analyzed to determine what proportion of the sample is microalgae and detritus.

Plankton tows will be performed to collect suspended organic matter from the water column. A 64 micron mesh phytoplankton net 90 cm long with a 30 cm diameter mouth will be used to trawl for 60 minutes. Separate 60 minute trawls will be performed on the incoming and outgoing tide in each reach and used for isotope analysis. A fraction of the sample from each trawl will be preserved with Lugol's solution and analyzed to determine what proportion of the sample biomass is phytoplankton, zooplankton, and detritus.

All samples will be sent to the lab for pre-analytical processing including homogenization, milling and encapsulation for GC/MS analysis of carbon, nitrogen and sulfur.

3.5.5 Task 5E – Benthic Survey (RI-P2-T5E)

Conceptual Basis and Rationale

As discussed more completely in the BERA Work Plan, the benthic community is not currently proposed as an assessment receptor for the BCSA given its likely limited utility in assessing and managing Site-specific risks. The Group recognizes, however, that a better Site-specific understanding of the benthic community condition in the BCSA is warranted before making a

[4] Composite samples for smaller invertebrates should be composed of the same number of individuals in each reach on a species-specific basis. Individuals in each composite sample should follow the 75 percent rule: the total length of the smallest individual in any composite should be no less than 75 percent of the total length of the largest individual in the composite sample.

final determination on its use for supporting management decisions. Therefore, Phase 2 will include a benthic community survey of the BCSA and appropriate reference areas (see Section 3.1.6 for reference site detail). The purpose of the survey would be to identify the composition and diversity of the benthic community at the Site and reference areas, and to preliminarily examine any potential trends in benthic community composition related to the distribution and magnitude of COPECs, regional contaminants, and physical and other non-CERCLA stressors. Secondarily, the overall importance of the benthic community to the aquatic food web studies of the BCSA will be investigated.

Scope of Work and Investigative Methods

To assist in the evaluation of benthic community structure in relation to bathymetric variability, sampling stations will be established in the main channel of Berry's Creek in each of the four BCSA segments. Ten benthic samples will be collected per study segment, with two samples paired at each of five separate mudflat areas within each segment. At each paired mudflat location, one sample will be collected from approximately midway up the mudflat at low tide, while the other sample will be collected near the thalweg in the subtidal area adjacent to the mudflat.

Benthic samples will be collected at each sampling station using a grab sampler (e.g., Van-veen, Eckman, modified petite ponar). Target depths used to qualify the acceptability of each sample will be based on BAZ depth horizons defined in Phase 1. Three ponar grabs will e collected (e.g., one port, one starboard, and one off the bow). The mud from each of these 3 grabs will be sieved and placed together in a single sample jar to make a sample. Retrieved sediment samples will be sieved in the field using 500 micron-mesh sieves and preserved with 10% neutral-buffered formalin. Samples will be labeled and shipped to the laboratory for benthic invertebrate mass determination and taxonomic identification to lowest practical taxon (e.g., species) of a 300 count subsample.

3.5.6 Task 5F – Qualitative Survey of Invertebrate/Insect Community (RI-P2-T5F)

Conceptual Basis and Rationale

A marsh invertebrate community study will be conducted as part of the Phase 2 program at the Site and in reference areas (see Section 3.6 for reference site detail). Both mercury and PCBs are key COPCs in the BCSA and both chemicals bioaccumulate in organisms and typically biomagnify in aquatic and terrestrial food webs. The terrestrial macroinvertebrate community in the marsh is composed of both aquatic emergent insects in addition to terrestrial macroinvertebrate herbivores, predators, and detritivores (Tewskbury et al., 2002; Kiviat and MacDonald, 2002). The goals of this study are to characterize the composition and relative abundance of the terrestrial macroinvertebrate community in the marsh, to characterize the distribution of the terrestrial macroinvertebrate community in the marsh habitat niches, and to gain an understanding of temporal trends in the community abundance over the summer. Resulting data will be used to better understand the potential for songbird exposure via the dietary pathway in the marsh, and if needed, to support Phase 3 studies to investigate potential exposures in song birds and bioaccumulation dynamics in the marsh invertebrate community.

The marsh invertebrate community is an important link between the marsh surface and upper trophic-level wildlife species. Recent work has shown that exposure in insectivorous song birds, even those relying primarily on terrestrial invertebrate prey in the floodplains of adjacent contaminated waterways, can approach or exceed exposures of avian predators of aquatic prey (Cristol et al., 2008). In two recent surveys in the tidal and nontidal Carlstadt-Moonachie marshes within the Meadowlands, sixty orders or families of invertebrates were captured in sweep net samples, and an additional thirty seven taxa of invertebrates were found in litter samples (Grossmueller, 2001; Kiviat and MacDonald, 2002). This diversity belies the fact that *Phragmites* marshes are characterized by concealed feeders that can provide a challenge to collection (Gratton and Denno, 2005). In addition, adult insect mass emergence events contribute another layer of complexity in optimal collection timing.

In addition to identifying the species comprising the marsh invertebrate community, the sampling will provide insights as to the most effective methods and timing for collecting marsh invertebrates should this need to be investigated further in Phase 3. Three collection methods will be evaluated for tissue collection efficiency and marsh terrestrial invertebrate community representation. To better understand potential seasonal trends in the composition and abundance of marsh invertebrates, a separate collection trap type will be deployed throughout the summer to assess the flying insect community diversity and abundance over the season. All four collection techniques will be used to characterize the abundance, diversity, and habitat niche distribution of the marsh terrestrial invertebrate community.

Scope of Work and Investigative Methods

Characterization of the terrestrial macroinvertebrate community will be conducted in three BCSA marshes by collecting and identifying macroinvertebrates in the marsh vegetation and in detritus on the marsh surface (Table 3-6). Sampling will occur in marsh areas cleared for sediment sampling activities, or if necessary, vegetation will be cleared for these sampling activities. The three marshes that will be sampled in the BCSA span the salinity gradient and are listed below along with the reach in which they are located:

- Berry's Creek Marsh (LBC)
- Walden Swamp (MBC)
- Eight Day Swamp (UBC)

The specific sampling locations in all of the marshes will be selected based on practical and safety considerations in addition to habitat characteristics observed during a reconnaissance Site visit the spring.

Sticky card traps will be deployed in each marsh throughout the summer (May through September). Sticky cards are a passive sampling technique that will be used to monitor the diversity and abundance of flying insects in the marshes over time. Sticky card traps will be collected and replaced at two week intervals from May through September. Two week intervals will resolve the seasonal patterns in insect diversity and abundance without contributing significantly to the level of effort by field crews. Each sticky card will be deployed at a height of approximately 1.5-meters (below the height of the *Phragmites*) and at a targeted distance of at least 50 m from the clearing-waterway interface to reduce edge effects (Harris, 1988). Insects captured by the sticky card will be killed by the trap and will not be preserved. Samples retrieved by the traps will be labeled and shipped to the laboratory for taxonomic identification to Family of a 300 count subsample. The results from the sticky card traps will be analyzed to determine peaks in insect diversity and abundance that will be used to inform the timing of possible Phase 3 marsh invertebrate tissue collection effort for COPC residue analysis. The results from the sticky card traps will also be used to characterize the marsh terrestrial macroinvertebrate community.

Three additional collection techniques will be used during a single sampling event in the summer:

- Light trapping
- Malaise trapping
- D-Vac sampling

Light trapping is a passive sampling technique effective only in low light (dusk, night, dawn) that can attract flying insects from a relatively wide area. The light traps will be deployed at a height of approximately 1.5 meters, (below the height of the *Phragmites*), at a targeted distance of at least 50 m from the clearing-waterway interface to reduce edge effects (Harris, 1988). The light trap position will limit the area from which insects are attracted, but will increase the site specificity of the captured insects. Insects captured by the light trap will be killed and preserved in 90% ethanol contained in a collection jar inside the trap. One light trap will be deployed for three consecutive nights in each of the marshes included in this study. Samples retrieved from the traps will be labeled and shipped to the laboratory for mass determination and taxonomic identification to Family of a 300 count subsample.

Malaise trapping is also a passive sampling technique. Malaise trapping is effective in all lighting conditions, but intercepts the flight path rather than attracting flying insects. The Malaise trap interception height is approximately 1.6 meters high, well below the height of the *Phragmites*, and will be deployed at a targeted distance of at least 50 m from the clearing-waterway interface to reduce edge effects (Harris, 1988). The Malaise trap position will maximize the flight interception in the marsh and attain high site specificity of the captured insects. Insects captured by the malaise trap will be killed and preserved in 10% formalin contained in a collection jar inside the trap. One Malaise trap will be deployed for three consecutive days and nights in each of the marshes included in this study. Samples retrieved from the traps will be labeled and shipped to the laboratory for mass determination and taxonomic identification to Family of a 300 count subsample.

The D-Vac sampling is an active sampling method and will focus on two compartments in the marsh to help differentiate the marsh habitat utilization by the invertebrate community. One sample will be collected from the standing vegetation, and a second sample will be collected from the detritus on the marsh surface. If possible, the two samples will be collected from different clearings to minimize sampling bias due to disturbance. For each compartment a sample will be defined as 30 minutes of active vacuum sampling. Vacuum sampling will start at a targeted distance of at least 50 m from the clearing-waterway interface and continue away from the interface will to minimize edge effects (Harris, 1988) and increase the site specificity. If possible, the two compartments be sampled from different clearings within each marsh to minimize sampling bias due to disturbance. One detritus vacuum sample and one vegetation vacuum sample will be collected in each of the marshes included in this study. Samples from each compartment will be collected, labeled, and placed on ice for transport to the lab within 24 hours. At the laboratory, the samples may be sorted from detritus using a Berlese funnel (which requires live specimens). The laboratory will perform mass determination and taxonomic identification to Family of a 300 count subsample.

A report will be generated that describes the marsh terrestrial macroinvertebrate community across the BCSA and compares community metrics such as abundance, species richness, and diversity from each of the marshes sampled. Life history data from the literature, in addition to sampling data will be used to assign collected taxa to different habitat niches within the marsh. The report will also compare the collection efficiency of the light trapping, Malaise trapping, and vacuum sampling. Finally the report will describe trends in the diversity and abundance of the invertebrate community over the sticky card sampling period.

3.5.7 Task 5G: Evaluation of BCSA Marsh Production, Functions, and Value

Conceptual Basis and Rationale

Phragmites marshes, including those of the Meadowlands and the BCSA, provide many important wetland functions and overall, salt marshes are some of the most productive ecosystems in the world. COPCs have been detected in marsh sediments at concentrations that are potentially above those present in reference areas. The potential effects of COPCs on the marsh vegetation will be assessed using two primary approaches: 1) measurement of plant production/biomass and 2) assessment of wetland functions and values. These two metrics provide an indication of marsh vegetation health, which will be examined across COPC concentration gradients in the BCSA and in comparison with reference areas.

Net primary productivity (NPP) is the rate of storage of organic matter in plant tissues that exceeds the respiratory use (Odum and Barrett, 2005). NPP of a plant community is the primary determinant for the amount of organic carbon cycling within a marsh environment. Field estimates of NPP in terrestrial ecosystems are generally based on peak aboveground biomass (including standing live biomass and leaf litter; Clark 2001), because other contributing processes (e.g., belowground productivity, decomposition, etc.) cannot be directly quantified in natural settings. Aboveground biomass provides a robust estimate of NPP, especially when used to compare plant communities with similar species composition (Leith and Whittaker, 1975).

Assessment of wetland functions and values is a second method of evaluating potential effects of COPCs the marsh community. Functions and values assessment quantifies ecosystem services (e.g. wildlife habitat, sediment stabilization, water quality, etc.) provided by different wetland habitats, thereby facilitating comparisons among BCSA reaches and between the BCSA and reference areas to evaluate effects of COPCs, if any.

Scope of Work and Investigative Methods

The proposed approach to evaluating potential COPC effects on plant communities in the BCSA will consist of a three-step process:

1. Remote sensing and GIS analysis of existing aerial photography and satellite imagery will be used to evaluate vegetation patterns with respect to Phase 1 COPC and other environmental data, and to identify suitable locations for comparison within the BCSA and the reference areas for a targeted field program.

2. Field measurement biomass measurements in selected marshes in the BCSA and reference areas to calibrate the remote sensing analysis and to supplement findings from Step 1. Data from the field surveys will be compared with COPC data from Phase 1 and Phase 2, between reaches in the BCSA, and between the BCSA and reference areas.

3. Assessment of wetlands functions and values using the Hydrogeomorphic Assessment Method (HGM) technique in both the BCSA and reference areas. HGM combines desktop studies with field observations to assess ten wetland functions: shoreline stabilization; maintenance of tidal marsh elevation; nutrient, organic carbon and contaminant flux; resident nekton utilization; non-resident nekton utilization; maintenance of invertebrate community;

wildlife habitat; plant community composition; plant biomass production; and maintenance of tidal wetland hydrology (Louis Berger Group, 2004). This is accomplished through identification and scoring of physical, chemical, and biological elements of the wetland habitat that relate to each function. Analysis of the assigned scores allows for the calculation of functional capacity units (FCUs) that facilitate comparisons between wetland areas. Comparable locations for HGM assessment in the BCSA and reference areas will be selected based on the findings of the remote sensing analysis.

The proposed approaches for evaluating marsh vegetation productivity and wetland functions and values are presented below and described in greater detail in the QAPP.

Remote Sensing Analysis Scope of Work and Investigation Methods

Remote sensing tools and aerial photograph analysis will be used to evaluate vegetation patterns in the BCSA and reference areas to identify areas of the marsh to be the focus of field studies. Satellite and aerial images collected by US Government programs are generally available (1972 through today) at 15 to 30 m resolution and will be used. Imagery available through NJDEP and NJMC will also be evaluated for suitability. If additional detail is needed to support the analysis, commercially available satellite images with resolutions up to 0.5 m will be used.

The satellite and aerial imagery will be used to develop qualitative and quantitative estimates of NPP and marsh canopy cover using well-established spectral indexes of vegetation cover, such as normalized difference vegetative index (NDVI) and enhanced vegetative index (EVI) (Swain and Davis 1978, Jensen 2005, NASA 2010). Comparisons of these indices and other environmental factors across the BCSA and in the reference areas will be used to select areas that are regarded as most comparable, for field evaluation of biomass/productivity, and functions and values.

Field Measurement of Productivity Scope of Work and Investigation Methods

A series of focused field measurements of stem density late in the growing season and peak total aboveground biomass will be used to directly assess the range of productivity of marsh vegetation in the BCSA study segments, and as a point of comparison to reference areas. The field sampling results will contribute both an independent estimate of NPP and empirical validation of the remote-sensing analysis for the BCSA.

Aboveground biomass will be collected from four transects in the BCSA. One representative transect will be established within the upper, middle and lower reaches of the BCSA (i.e., Berry's Creek Marsh in LBC, Tollgate Marsh in BCC, Walden Swamp in MBC, and Eight Day Swamp in UBC), with guidance from the results of the remote-sensing analysis. Three sample plots will be established along each transect. Transects will extend approximately 300 feet from the main stream channel into the marsh, with 0.5 to 1.0 m^2 sampling plots spaced approximately 100 feet apart along the transects.

Prior to harvesting, a stem count will be conducted within the sample plot, and all plant species comprising more than 5% of the plant community within the plot will be identified. Because of the predominance of Phragmites in the BCSA, biomass measurements in the reference areas will be limited to plots where Phragmites is the primary species present. All aboveground biomass will then be harvested by cutting as close to the marsh surface as possible. As an indicator of organic carbon input to the system, leaf litter within the plots will also be collected. Aboveground biomass and leaf litter will be dried separately and weighed to quantify biomass from each plot. Differences between the NPP/biomass estimates derived from remote sensing and field measurements will be evaluated and uncertainties quantified.

These measurements will be related to COPC data from Phase 1 and Phase 2 to evaluate relationships, if any. Biomass/NPP will also be compared between reaches within the BCSA, and between the BCSA and reference areas, both graphically and statistically. These results will also be applied to the HGM analysis of functions and values.

HGM Scope of Work and Investigation Methods

Comparable locations for HGM assessment in the BCSA and reference areas will be selected based on the findings of the remote sensing analysis. HGM data forms will be completed for three locations in each study segment for the BCSA (minimum 12 locations), or one data form for each distinct wetland type, whichever is greater. Additional transects may be proposed to account for variability in the marshes if the remote-sensing analysis indicates that further characterization is warranted. Analysis of the completed data forms will enable preliminary characterization of the ten wetland functions listed above. Fish and invertebrate community data collected as part of Tasks 5C, 5D, and 5E will be used in the HGM analysis of functions and values, to the extent they provide relevant information. The completed analysis will result in the development of FCUs for the BCSA and reference areas. These measurements will be related to COPC data from Phase 1 and Phase 2 to evaluate relationships, if any. Functions and values will also be compared between reaches within the BCSA, and between the BCSA and reference areas, both graphically and statistically.

3.6 Task 6 – Reference Site Evaluation

The reference site data collected during the Phase 1 program showed that mercury, methyl mercury and PCBs are also regional contaminants. These chemicals were detected in sediments, water and mummichog from the reference sites, though at concentrations below those observed in the BCSA. However, no white perch or blue crab was collected from the reference sites for chemical residue analysis in Phase 1. White perch and blue crab are mobile species that can move into and out of the BCSA on a seasonal basis. Because no Phase 1 reference site data was

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collected for these species, no data are available with which to assess regional contaminant burden of these chemicals in these species. Therefore, the Phase 2 program includes tissue residue sampling for both white perch and blue crab. Additionally, mummichog are to be collected again at each reference site location to support an understanding of annual variability in tissue residues in this species. Finally, marsh sediments will be sampled during Phase 2. Marsh sediments were not sampled in the Phase 1 program. To provide comparison to BCSA findings, the following sampling will be done in each of the three reference areas:

- Biota COPC residue
- Marsh sediment
- *Phragmites*
- Fish Community Study
- Food web
- Benthic Survey
- Survey of Marsh Invertebrates/Insect Community

With regard to terminology to discuss this analysis, the Mill Creek and Bellman's Creek represent the Hackensack River Background (HRB) and Woodbridge River represents the Regional Urban Reference (RUR) as defined by Ehrenfeld (2007). This framework will be used in subsequent data analysis here and in Task 8.

3.6.1 Task 6A – Biota Sampling

Conceptual Basis and Rationale

Phase 2 efforts will involve collection of mummichog, white perch, and blue crab at each of three reference sites (Bellman's Creek, Woodbridge Creek, and Mill Creek). The sampling locations will be the same as were used for mummichog sampling in the Phase 1 investigation and are shown in Figure 3-15. There are 21 reference locations: nine in Bellman's Creek, nine in Woodbridge Creek, and three in Mill Creek. Mummichog, white perch, and blue crab will be collected from each of these locations. Analogous to the investigation in the BCSA, white perch will be analyzed as both whole-body and fillet only samples. Fillets will be processed as scales-off, skin-on. Blue crab will have the edible muscle tissues (i.e., all leg and claw meat, back shell meat and body cavity meat) removed for analysis and the remaining carcass will be analyzed as well. Three locations from each reference site will also have the hepatopancreas removed and analyzed separately from the muscle tissues.

Scope of Work and Investigative Methods

All sampling will be conducted using the collection and sample processing methods described in Section 3.1.5.1 for the BCSA tissue samples. All samples will be analyzed for mercury, methyl mercury, and PCBs, lipids, stable isotopes, and moisture content as per Table 3-8.

3.6.2 Task 6B – Marsh Sediment Sampling

Conceptual Basis and Rationale

A review of marsh sediment sample data in the BCSA during Phase 1 revealed notable patterns of metals in marsh sediments. These observations included the following:

- Elevated methyl mercury results commonly observed in 0 to 5 cm marsh sediments, with more elevated concentrations in 10 to15 cm sediments;
- Total mercury, chromium, cadmium, and zinc concentrations elevated above waterway concentrations in certain study segments; and
- Manganese concentrations at particularly high levels compared to waterway concentrations in UBC and MBC.

It is expected that the high organic content and variable redox conditions in marsh sediments may have a strong effect on metals sequestration, mobilization, and transformation. In addition, it is possible that these geochemically - driven processes may lead to similar effects in reference areas, away from the industrial sources in the BCSA. It is necessary to understand the extent to which this behavior is brought about by the nature of the marsh as opposed to BCSA-specific patterns of COPC presence and transport. Additionally, it is desirable to understand the extent to which these effects may vary among reference sites, particularly since one of the BCSA reference sites (Mill Creek) has a history of sewage treatment plant impacts, which may contribute to observed metals concentrations.

Scope of Work and Investigative Methods

In Phase 2, three to nine (0 to 15) cm marsh sediment cores will be advanced across each of the three reference sites (Bellman's Creek (9), Mill Creek (3), and Woodbridge River (9)). The same sampling intervals (0 to 5 cm and 10 to 15 cm) will be applied as have been applied in the BCSA marsh sampling, and the analytical program (Table 3-8) will correspond to that of the BCSA marsh work.

The sampling locations shown in Figures 3-15 have been matched to existing reference site sampling locations that best correspond to the salinity values of UBC and MBC, i.e., they have been matched to UBC- or MBC-appropriate waterway sampling points. In the case of Mill

Creek, which is relatively saline, marsh sediment will be collected near the most upstream waterway COPC sampling location. Field modifications will be made as necessary to sample in *Phragmites* marshes that most closely match the vegetative characteristics of BCSA marshes.

In addition to the COPC cores, three locations per reference site (total of 9) will be utilized to assess mercury methylation/demethylation dynamics. Methyl mercury concentrations were elevated in the 0 to 5 cm and 10 to 15 cm intervals in the Phase 1 sampling for the BCSA site. Task 3D describes a scope of work to assess mercury methylation/demethylation within the BCSA. A similar study will be conducted in the reference sites. These cores will be co-located with cores for the complete COPC list.

Sediment cores will be collected to a depth of 16 cm (approximately 6 inches) below the marsh surface. This depth includes the interval where metals typically are highest in concentration and is a reasonable interval to evaluate as most biological productivity (i.e., most biomass) occurs in this horizon. Upon retrieval, the cores will be sectioned in 2 cm intervals. Sediment redox and pH measurements will be collected from each 2 cm interval immediately upon sectioning by inserting the redox/pH probe (e.g., Orion 250A or similar) directly into the sediment. Three measurements will be collected along a horizontal transect across the face of the core for each depth interval to ascertain the degree of variability in redox and pH both vertically and horizontally.

Sediment samples will also be collected from each 2 cm interval for total and methyl mercury analysis. Ancillary parameters for analysis will include pH, sulfide, sulfate, and TOC. In addition, salinity will be measured in the water at the bottom of the core before backfilling the sediment core location. Data from these high resolution cores will be used to support an analysis of factors controlling mercury methylation/demethylation in reference site marshes for comparison with the BCSA site findings.

Marsh sampling will be performed using a decontaminated stainless steel shovel as described in the FSP and SOPs. Protocols will be as specified in the project documents. The analytical program will be performed as shown in Table 3-8.

3.6.3 Task 6C – *Phragmites* Sampling

Conceptual Basis and Rationale

As an additional component of investigating the exposure point concentrations and potential exchange of COPCs between the waterways and marshes, Task 3E addressed the sampling of *Phragmites* material from locations within the BCSA. Task 6 C includes a similar study that will provide results from the three reference areas for comparison.

The first type of sampling will be done to evaluate potential exposure point concentrations in marsh invertebrate/insect habitats.

- *Phragmites* **Leaves:** Leaves from living plants will be collected

- **Marsh Surface:** Recently dead and decaying coarse plant material will be collected from the base of the plants.

- **Detritus Layer:** The detritus layer just above the root zone sediments will be collected.

The second type of sampling will be done to evaluate potential exposure point concentrations for mammals in the marsh system.

- *Phragmites* **Roots:** The root layer will be sampled.

In addition to standard COPC analysis, each of these samples excepting *Phragmites* roots, will also undergo stable isotope analysis to trace the carbon, nitrogen, and sulfur significance through the food web.

Scope of Work and Investigative Methods

In Phase 2, four types of *Phragmites* samples will be collected at a total of three locations within each of the three reference sites. All four samples will be collected at each of the locations. Locations are shown in Figures 3-15. The analytical program for Task 6C will focus on COPCs, as shown in Table 3-8.

3.6.4 Task 6D – Fish Community Survey

Conceptual Basis and Rationale

To allow for a comparison of BCSA and reference site fish communities, Phase 2 efforts will involve sampling to characterize the fish community at each of three reference sites (Bellman's Creek, Woodbridge Creek, and Mill Creek). Sampling will be performed in three segments in Bellman's Creek, three segments in Woodbridge Creek, and one segment in Mill Creek, each corresponding to the segment breakdowns previously used in the Phase 1 program. Sampling locations in the reference sites will be based on a combination of physical or habitat-based characteristics and the relative proximity of Phase 1 tissue sampling. Comparability in physical or habitat characteristics between BCSA and reference areas is important to ensure that significant differences do not inappropriately skew community metrics. Physical and habitat characteristics (e.g., water depth, salinity) for the reference sites were recorded during the Phase 1 program and the reference sites were concluded to be reasonably comparable to the BCSA. This information will be again recorded in Phase 2 along with additional habitat information such as the presence of emergent or aquatic macrophytes and presence and extent of mudflats. Collectively, this information will be used to support a better understanding of the similarities between the BCSA and the reference sites. Proximity to previous sampling locations will ensure that data from Phase 1 and Phase 2 can be appropriately aligned and interpreted.

Scope of Work and Investigative Methods

All sampling will be conducted concurrent with and using the collection and sample processing methods described in Section 3.1.5.3 for the BCSA fish community survey. Based on samples collected, comparisons will be made between segments on the basis of water quality parameters (temperature, dissolved oxygen, salinity) and fish community metrics (relative species abundance, richness, evenness, and diversity).

3.6.5 Task 6E – Food Web Study

Conceptual Basis and Rationale

As a component of investigating the spatial variation in food web structure and potential exposure pathways, Task 5D addressed two related investigations in the BCSA: 1) an analysis of prey and other food items in the gut contents of fishes to quantify composition of their diets, and 2) an analysis of stable isotope composition of selected components of the food web to assign trophic level and determine the ultimate source of energy for key receptors. Task 6E includes a similar pair of studies that will provide results from the three reference areas for comparison.

Samples will be collected from all three reference areas during July, concurrent with the Phase 2 fish community study.

For the gut content study and the isotope study, all biota components that are sampled in the BCSA will also be sampled in each of the reference areas.

Scope of Work and Investigative Methods

All sampling will be conducted concurrent with and using the collection and sample processing methods described in Section 3.1.5.4 for the BCSA food web study.

Based on samples collected, comparisons will be made between the BCSA and the reference sites on the basis of both the gut content study and the isotope study; data will be used to support development of food web diagrams, assess spatial heterogeneity in food web structure, and support COPC exposure analysis in the BERA.

3.6.6 Task 6F – Benthic Survey

Conceptual Basis and Rationale

A stratified sampling approach aimed at assessing the diversity of the BCSA benthic community was outlined in Task 5E (see Section 3.5.5). The Phase 2 program will also include a reference area assessment in Task 6F, but will focus on Bellman's Creek alone for comparison.

Scope of Work and Investigative Methods

All sampling will be conducted concurrent with and using the collection and sample processing methods described in Section 3.5.5 for the BCSA benthic invertebrate survey. Sampling will concentrate in the Bellman's Creek reference area where salinity matches the UBC, MBC, and BCC/LBC study segments (as observed in the Phase 1 reference survey). Benthic samples will be collected from mudflats within three segments of Bellman's Creek previously sampled as part of Phase 1 surface water and sediment sampling. Within each segment, two samples will be paired at three separate mudflat areas, with one sample collected from approximately midway up the mudflat at low tide and the other near the thalweg in the adjacent subtidal area.

3.6.7 Task 6G – Qualitative Survey of Invertebrate/Insect Community

Conceptual Basis and Rationale

As a component of investigating the potential for songbird exposure via the dietary pathway in the marsh, Task 5F addressed the sampling of the marsh invertebrate community from locations within the BCSA. Task 6G includes a similar study that will provide results from the three reference areas for comparison.

Scope of Work and Investigative Methods

All sampling will be conducted concurrent with and using the collection and sample processing methods described in Section 3.1.5.6 for the BCSA qualitative survey of the invertebrate/insect community. Sampling locations in three marshes along the salinity gradient will be selected in Bellman's Creek and Woodbridge River; sampling locations in one marsh will be selected at the Mill Creek reference site. Specific sampling locations will be based upon habitat characteristics and practical considerations within the reference areas identified during a site reconnaissance visit in the spring. Based on samples collected, comparisons will be made between segments on the basis of invertebrate community metrics (relative species abundance, richness, evenness, and diversity) and habitat niches (marsh detritus, standing vegetation).

3.6.8 Task 6H: Evaluation of Marsh Production, Functions, and Value in Reference Sites

Conceptual Basis and Rationale

The potential effects of COPCs on the marsh vegetation will be assessed using two primary approaches: 1) measurement of plant production/biomass and 2) assessment of wetland functions and values.

Scope of Work and Investigative Methods

Task 5G outlined the approaches to be used in the BCSA. The same approach will adopted for each of the reference sites and consists of:

1. Remote sensing and GIS analysis of existing aerial photography and satellite imagery will be used to evaluate vegetation patterns with respect to Phase 1 COPC and other environmental data, and to identify suitable locations for comparison within the BCSA and the reference areas for a targeted field program.

2. The field program will consist of data collection of biomass in selected marshes in the BCSA and reference areas to calibrate the remote sensing analysis and to supplement findings from Step 1.

3. HGM to assess wetlands functions and values.

The proposed approaches for evaluating marsh vegetation productivity and wetland functions and values were presented in Task 5G and are described in the QAPP.

3.7 Task 7 – Atmospheric Deposition and Air Monitoring

Task 7 examines the potential contribution of COPCs from long-range atmospheric deposition (Task 7A) and the potential flux of COPCs (Task 7B) to the Berry's Creek environment.

3.7.1 Task 7A - Atmospheric Deposition Assessment

Based on the findings presented in the Phase 1 report, atmospheric deposition is a source of a variety of chemicals entering the BCSA watershed. Data from the New Jersey Atmospheric Deposition Network (NJADN) indicates that a number of organic chemicals and metals, including PCBs and mercury, will deposit to the BCSA environment. Atmospheric deposition overall is therefore a potentially material ongoing source of contamination in the study area.

More analysis is needed to better understand the potential significance of atmospheric deposition to total contaminant loading in the BCSA and the significance of this deposition in defining baseline contaminant concentrations in the study area. The Phase 2 study will consist of additional desktop research to develop a mass balance and related exposure point concentrations in the BCSA for atmospheric loading. This information will be useful in understanding the magnitude of atmospheric loading to the study area and defining a baseline level of input to the BCSA under current or post-remedy conditions. The focus of the atmospheric deposition assessment in Phase 2 will be mercury and PCBs, which have been identified as primary COPCs for the Site, and a subset of TAL metals (beyond mercury) that are present in BCSA sediments at regionally elevated concentrations (e.g., zinc, manganese).

A fugacity model approach will be used in the Phase 2 study of atmospheric deposition. This approach represents a multimedia environmental fate and transport model that allows significant flexibility in problem formulation and computational complexity. The modeled environment is separated into a series of connected compartments (e.g., air, water, and soil). The model is then used to describe mass transfer and the relative distribution of the contaminant for the specified compartments. The analysis can be conducted within a standard spreadsheet environment where it is easily adapted to increase model refinement and computational complexity only as needed to better define relationships within or between compartments.

The Phase 2 fugacity approach will be a simple four compartment model that includes air, water, sediment and soils within the BCSA. The model will assume steady-state conditions of mass transfer by bulk and diffusive processes. The bulk processes will be the various types of atmospheric loading to BCSA that were quantified in Phase 1 (i.e., dry particle deposition, gas-phase deposition and wet deposition). Diffusive processes in the model will reflect two-way transfer between compartments of the material received from atmospheric loading, such as gas-phase deposition/volatilization across the air water interface and sorption/desorption from sediments into water. The model results would provide estimates of the distribution of COPCs entering the system from atmospheric loading across the four compartments.

3.7.2 Task 7B – Air Monitoring

Conceptual Basis and Rationale

As indicated in the mercury CSM (Geosyntec, 2009), mercury exchange between the atmosphere and surface water/sediment is a dynamic, bi-directional process. Volatilization of mercury that is present in Berry's Creek sediments and surface water may be a potential local source of mercury emissions to air. Though the overall strength of this source is not expected to be sufficiently large to result in unacceptable human health risks, an air monitoring program for mercury has been included in the Phase 2 scope to address this source consistent with comments received from USEPA on the Phase 1 report, and recommendations received from the Contaminated Sediments Technical Advisory Group (CSTAG). The program to be conducted during Phase 2 is designed to obtain data that represent the reasonable maximum exposure concentrations for human receptors in the BCSA.

In preparing this sampling program to measure the mercury concentration in air, three general approaches to estimating exposure concentrations (USEPA, 1989) were considered:

- Ambient air monitoring;
- Emission measurements coupled with modeling; and,
- Emission modeling coupled with dispersion modeling.

Ambient air monitoring was selected because it provides direct measurement of air concentrations, thereby substantially reducing the uncertainty in the analysis compared with modeling approaches. In addition, some air monitoring data from the BCSA already exists for comparison.

The total flux of mercury vapor (Hg^0) will be affected by mercury concentration in surface water/sediment, as well as a number of environmental factors such as temperature, sunlight intensity, tidal cycle, wind and background conditions. In general, mercury flux is predicted to be greatest under sunny and warm conditions and at low tide, when mudflats are exposed to air.

Two recently conducted studies (Cardona-Marek et al. 2007; Lioy et al. 2008) have investigated mercury vapor concentrations in air above the water surface at various locations in Berry's Creek. Cardona-Marek et al. (2007) measured mercury concentrations (measured at a height of 3m above the water surface) during summer and fall sampling periods and reported concentrations in the range of 1.87 to 2.61 ng/m^3 (mean±SD of 2.15±0.24 ng/m^3). Lioy et al (2008) measured mercury concentrations in breathing zone air in summer and reported concentrations in the range of 23.2 to 46.1 ng/m^3 (mean±SD of 35.8±5.5 ng/m^3). No seasonal and/or temporal differences were evaluated in either study.

Regional background concentrations of mercury near the BCSA have been reported to be in the range of 2 to ~5 ng/m^3 (Aucott et al., 2009; Goodrow et al., 2005; Garetano et al., 2006; Garetano et al., 2008). Risk-based screening levels (RBSLs) for mercury vapor (Hg^0) for residential and industrial receptors are 310 and 1,310 ng/m^3, respectively (USEPA, 2010). In the BCSA, kayakers (or canoers) are the receptor group potentially exposed to vapor concentrations in the tidal area. These receptors will be directly above the water surface (e.g., 1 m or less) and thus nearest the source of possible mercury emissions. Other recreational users in the BCSA will be more removed from potential sources and therefore will experience lower exposure concentrations due to dilution during transport. Anglers and crabbers recreating from the shoreline areas along the BCSA are expected to be exposed to lower concentrations than kayakers due to greater attenuation of concentrations before reaching a breathing zone more distant from the source and at a higher elevation. Anglers or crabbers who access the area by other types of boats also will experience lower breathing zone concentrations than kayakers, given that they are elevated above the water surface to a greater height. No recreational activities have been observed in mudflat areas due to the soft and deep mud which makes access difficult. Swimming does not occur in the BCSA and is unlikely to occur in the future give the overall poor accessibility of the waterways, the hard to traverse nature of the shoreline areas, the soft mud substrate, and high (above state standards) fecal coliform counts that make swimming hazardous. If swimming did occur, exposure concentrations would be comparable to that for the kayaker but the overall exposure duration would be lower so that potential exposures would be lower.

The study by Lioy et al. (2008) indicates that the mercury in breathing zone air in the BCSA may be elevated relative to regional background conditions, albeit still below risk screening levels. To further refine the development of the CSM for mercury and to support the overall evaluation of human health risks in the BCSA, Phase 2 includes sampling to measure mercury vapor concentrations in air above the Berry's Creek water surface. The focus of the evaluation will be to measure mercury vapor concentrations within the expected breathing zone of a recreational boater in the study area. Measurements will be collected during the three seasons that have the greatest recreational activity (spring, summer and fall). Summertime measurements are known to represent conditions conducive to maximum mercury flux, related to higher temperatures and higher sunlight intensity.

Scope of Work and Investigative Methods

To further develop the BCSA CSM, particularly with regard to factors that can influence how mercury residues in BCSA media contribute to ambient levels of mercury, and to provide empirical data to support the human health risk assessment for recreational users of Berry's Creek the following scope of work has been developed.

A kayaker is the target recreational receptor. Mercury concentrations in breathing zone air (assumed to be approximately 1 meter above the water surface for a kayaker) will be measured from each of the four BCSA study segments (UBC, MBC, LBC, and BCC), one of the existing reference areas (Bellman's Creek), and an urbanized background location within the BCSA airshed and generally upwind, but away from the waterways and marshes. Each of the BCSA reaches will be sampled to provide estimates of representative air concentrations in the breathing zone of a recreational boater throughout the study area.

The Bellman's Creek reference area will be sampled to represent mercury vapor concentrations that occur in the air above tidal creeks with exposed mudflats and surrounding *Phragmites* marsh, similar to that found in the BCSA, but where mercury concentrations are representative of the urban waterways of the Meadowlands. The mercury detected in sediments and surface water in Bellman's Creek in Phase 1 appears to be indicative of regional background levels, and as is the case in the BCSA, can be a local source of mercury in breathing zone air.

The urbanized background location within the BCSA will provide information on levels of mercury in air that may be present due to contributions from the regional airshed. The urbanized background location has been selected to be an area removed from the waterway and marshes but still within the BCSA. Four locations that parallel Berry's Creek on the west side (generally upwind) will be selected to provide representative urban background conditions.

Mercury concentrations in air will be obtained using the portable Ohio Lumex RA-915+ instrument. This instrument is sufficiently sensitive to support comparisons to other studies, and most importantly to support evaluations of potential human health risks.

Each sampling event will occur over a one day period to ensure comparability of the data. All sampling will occur during daylight hours between 10 am and 2 pm, and, to the extent feasible, during the period between middle ebb tide and middle flood tide, when the mudflats are exposed. Sampling during these periods will provide data that are representative of reasonable maximum exposure concentrations.

The four primary study reaches in Berry's Creek, the reference area, and urban background locations will be sampled separately during each season, with 20 discrete samples distributed across each area. The total number of samples is 360, and the number of samples per location is sufficient to provide for statistical comparisons. The location of the samples will overlap the areas that were sampled for biota and sediment during pervious sampling activities.

Location	**Number of Samples**			
	Spring	**Summer**	**Fall**	**Total**
UBC	20	20	20	60
MBC	20	20	20	60
BCC	20	20	20	60
LBC	20	20	20	60
Bellman's Creek	20	20	20	60
Urban Background	20	20	20	60
Total	120	120	120	360

For the urbanized background area, five samples will be collected in 5 minute increments over one hour at each of the four locations during the hours of approximately 10 am to 2 pm, to correspond to the other samples being collected over the waterways. A total of twenty urban background measurements will be collected for each season.

Concurrent information regarding meteorological conditions (temperature, wind direction, wind speed) will be obtained from nearby stations (e.g., Teterboro Airport). Some of this information, such as temperature, will also be collected on the sampling boat. Sunlight intensity will be monitored on the boat during the sampling periods using an instantaneous light intensity meter such as the Licor Model LI-200 Pyranometer Sensor (or equivalent).

The resulting data will be evaluated as follows:

- The data will be summarized by BCSA segment, reference location, and the urbanized background location, by sampling event and across sampling events.

- The data will be parsed to assess seasonal differences in mercury air concentrations, differences as they may relate to meteorological conditions (e.g., temperature, prevailing wind direction), tidal status, flux intensity, and other similar factors, and whether there are differences between the BCSA and the reference location.

- The results will be compared to those from prior published studies (e.g., Lioy et al., 2008) and other monitoring data [e.g., state-wide monitoring data from NJDEP (2009)] that may be available.

- Representative mercury in air exposure concentrations will be developed for each BCSA study segment and for the entire BCSA, as well as the reference location, and the urbanized background location for use in the risk assessment.

3.8 Task 8 – Regional Background Data Review

Throughout the Hackensack Meadowlands, there has been extensive and extended urbanization and industrial activity, as well as major human changes to the landscape and hydrology (see RI/FS Work Plan). The data collected from the three reference sites during Phase 1 confirmed that PCBs, methyl mercury, mercury, PCBs, TAL metals, and a number of other chemicals are present in the region at concentrations that are elevated above risk-based benchmarks. Regional contaminant levels have a significant influence on the chemical concentrations that can be realistically achieved at any given site, and therefore need to be considered as part of the development of remedial action objectives (RAOs) and remedial alternatives. USEPA (2005a) acknowledges the need to differentiate between natural and anthropogenic contamination not related to the site and contamination due to site-related hazardous substance releases as part of the overall risk management strategy for contaminated sediment sites (USEPA 2005a, Section 2.1.3).

The reference sites evaluated during Phase 1 and proposed for Phase 2 represent environments that are similar in habitat and watershed characteristics to the BCSA, but are not directly hydrologically connected to the BCSA. As discussed in the Phase 1 Work Plan and refined in the updated CSM presented in the Phase 1 report, the Hackensack River is an important source of sediments and water into the BCSA and therefore, chemicals that are present in the River will enter the BCSA with the daily tides. Additionally, mobile aquatic species, such as fish and crab, can enter the BCSA from the Hackensack River as part of regular seasonal movements into and out of estuarine creeks in the general region. Bellman's Creek and Mill Creek are also tributaries to the Hackensack River, and are therefore subject to the same physical, chemical and biological inputs from the Hackensack River that may be expected in the BCSA. Woodbridge River is not tributary to the Hackensack River, but like the BCSA is part of the broader Hudson-Raritan Estuary.

To further assess the potential influence of regional inputs on the BCSA sediments, a literature review of regional concentrations of primary and secondary COPCs in sediments, surface water, and biota will be completed. The objective of this review will be to assess concentrations of COPCs in the BCSA media that may be attributable to urban background, and that may be expected in the study area following remedial actions. Studies related to regional COPC concentrations will be identified through searches of peer-reviewed literature, agency repositories, and online resources. Identified datasets will be qualitatively evaluated to assess data quality. The following factors will be considered prior to including identified data in the evaluation of regional background concentrations:

- general study information (i.e., source, date, geographic extent, number of samples);
- data availability (i.e., media sampled, COPCs analyzed, ancillary parameters measured [e.g., TOC, sulfide, tissue lipid content], sample locations/coordinates); and,
- quality assurance/quality control procedures (i.e., existence/availability of a QAPP, sample collection methods, chains of custody, QA/QC sample collection, analytical methods, data validation, etc.).

In addition, to provide context for this regional background data review and interpretation of sediment data from the BCSA, an analysis of the factors and conditions influencing sediment supply, transport, and stability will be completed for the BCSA and wider Hackensack Meadowlands. The analysis will identify changes, both natural and anthropogenic, that occurred during the periods: Pleistocene, Holocene, Colonial Times, 1800's, 1900's, and current. Discussion of each time period will include, but not necessarily be limited to, the following factors: water flow/balance drainage modifications; sediment loading; salinity changes; wetland vegetation changes; major storm events; and sea level rise.

The areas of focus for this evaluation will be the Hackensack River, Newark Bay, Kill Van Kull, and Arthur Kill. Published COPC data from the broader Hudson-Raritan Estuary may also be evaluated as necessary to develop a comprehensive database. Data included in the evaluation will be primarily focused on studies conducted between 1990 and 2010 to ensure relevance to current conditions, and because of improved analytical methods as compared to earlier studies (particularly for mercury). Larger sampling programs with well-documented QA/QC procedures will be preferred, but smaller studies may also be included if sufficient information is available to determine that data quality is satisfactory.

Data that meet the above criteria will be used to create a database of regional COPC concentrations. For fish tissue, COPC data will be evaluated for bulk tissue concentrations as well as lipid-normalized concentrations. Bulk sediment COPC concentrations will also be evaluated with respect to TOC and/or sulfide concentrations. Filtered and unfiltered surface water concentrations will be evaluated separately. Regional background concentrations of primary and secondary COPCs in sediment, surface water, and biota will be calculated using descriptive statistics for the region as a whole. Analysis of targeted areas (e.g., the Hackensack River) may also be completed. The results of this evaluation will be presented in the Phase 2 report.

3.9 Task 9 – Data Management/Data Validation/Field Audits

Data management and data validation procedures are described in detail in the Data Management Plan (DMP) and Quality Assurance Project Plan (QAPP) respectively, and summarized in detail in the Phase 1 approved work plan. In general, all data validation and data management will be done in a manner consistent with the approved Work Plan. Field, laboratory and office audits will be conducted as per the approved QAPP. A Phase 2 QAPP amendment, including an updated Field Sampling Plan (FSP) and Standard Operating Procedures (SOPs) has been submitted to USEPA under separate cover.

3.9.1 Data Flow

Data generated during the RI/FS process will include field parameters (e.g., pH, DO, ORP, turbidity, water temperature, salinity of surface water samples); laboratory analyses of environmental samples; biological data (e.g., species counts); spatial data (e.g., physical template observations, geophysical data); and metadata associated with all of the above (e.g., field notes, sample identification; level of data validation, described further in the QAPP). All data generated during the RI/FS process will be stored in the project Database Management System (DMS). Additional data including tide elevations and other hydrodynamic data will be collected by automatic datalogging devices and either routinely downloaded into, or perpetually accessible by, the DMS. The data flow from sample collection through to its use in analyses and reporting will be as per the procedures described in the approved Phase 1 project documents. The following are the key steps that will be followed:

1. Sample Collection and Analysis
2. Data Assembly in Database
3. Data Validation

4. Data Analysis

5. Data Output and Presentation

6. Submittal of Validated Data to Group and USEPA

3.9.2 Data Validation

Analytical data will be validated per the validation standard operating procedures listed by USEPA Region 2 under the RCRA and CERCLA Field and Data Validation Standard Operating Procedures (http://www.epa.gov/region2/qa/documents.htm), the National Functional Guidelines for Contract Laboratory Program Data Review, and the specific laboratory-supplied analytical and sample preparation standard operating procedures (SOPs). Field data will also be validated against the SOPs and acceptance criteria contained in the project specific UFP-QAPP

As per Phase 1, tier III data validation will be performed on a complete analytical batch or sample delivery group for each method and matrix at the onset of Phase 2. Once this validation has occurred and it has been established that the laboratory(ies) are following the specified protocols, to the specified level of quality, meeting the specifications of the QAPP, and providing the necessary data deliverables, i.e., demonstration of a acceptable performance, then a revised validation protocol will be employed.

For EPC data collected in Phase 2 and beyond, a customized Tier II validation will be performed for 50% of data upon successful completion of Tier III validation for one SDG per matrix per method per year. For non-EPC data, 25% of Phase 2 and Phase 3 data will undergo a customized Tier II validation. Remaining data will undergo validation screening by the automated data quality system and if any quality issues are identified by the screening, a customized Tier II validation will be performed. The quality of all of the data collected in Phase 2 and beyond will be validated using this tiered approach.

BCSA Project Customized Tier II Validation Approach

The customized, Tier II, validation that will be performed on BCSA data deliverables includes a much higher level of validation than the standard Tier II validation. The customized, Tier II, validation process can only be performed if a full level IV or CLP-like (hereafter referred to as a "full" data package) data deliverable is supplied by the laboratory. Full packages will be received for all of the BCSA analytical results and will consist of:

- a case narrative (signed by the laboratory manager or their designee);
- sample results;
- the quality assurance sample results that are associated with the samples;

- a copy of the COC that was received with the samples; and,
- the laboratory receiving documentation, plus all of the raw data that is associated with the samples, including chromatograms, standard preparation information, sample preparation sheets, sample traffic sheets, analytical run logs, standard chromatograms, initial and continuing calibration information, calculations, and chromatograms or raw data, a cross reference sample identification page, and all of the raw data associated with the associated QC samples.

The BCSA customized, Tier II, validation has been developed using the forms in the TestAmerica (TA) customized data summary package, the QC summary section at the front of each analytical section of the deliverable, and the calibration summary section of each analytical section. The BCSA specific data summary section prepared by TA will include much more information than a Level II data deliverable and includes not only the sample results per test, but also all of the associated QA results.

Using SW-846 Method 8270C as an example, the data summary will include:

- individual sample results, a tabular summary for surrogate recoveries for all samples (including dilutions) and relevant quality control (QC) samples;
- laboratory control spike (LCS) sample recovery forms for each LCS that was processed during the analytical sequences;
- matrix spike/matrix spike duplicate (MS/MSD) results;
- method blank summary forms which indicate the method blank results as well as the samples associated with the method blank; and
- the tabular internal standard area and retention time summary forms.

The QC summary section of the SW-846 Method 8270 includes much of the same information with the addition of all of the pertinent instrument performance checks ("tunes") that are associated with the analytical sequences. The calibration section includes the calibration summary forms that indicate the type of curve fit applied to the data, the relative response factor, and relative retention times of the compounds.

The BCSA customized Tier II checklist reflects the review of key data from the full data package sections referenced above, resulting in a customized "Tier II" data review. It is important to emphasize that this level of validation must be performed by an experienced Tier III validation specialist. Items in the check list were based on the analytical method requirements, EPA Region 2 validation guidance for SW-846 Method 8270D, and U.S. EPA CLP National Functional Guidelines for Organic Data Review, 2007.

In the event that a laboratory nonconformance or systematic error is identified during the customized Tier II validation which results in erroneous data results or data of unacceptable quality, the laboratory will be asked for resolution of the issue and Tier III validation will be performed on the laboratory deliverable until acceptable laboratory performance is again established.

3.10 Task 10 – Modeling

Section 8.1.10.1 of the RI/FS Work Plan calls for the preparation of a modeling plan as a part of the Phase 1 program. This modeling plan was provided as Appendix H of the Phase 1 Site Characterization Report (Geosyntec/Integral, 2010). The modeling plan describes the sequential process by which models will be applied to support site management decisions, the system components to be modeled, and the types of data collection and analyses that will be conducted to support model refinement throughout the RI/FS process.

Models will be developed for the following components:

- Physical System – with a focus on hydrodynamic and sediment/particle transport modeling
- Chemical System – with a focus on characterizing the fate, transport and bioavailability of the primary COPCs
- Biological System – with a focus on understanding the biological uptake and food-web transfer of primary COPCs.

The modeling framework is founded upon the CSMs. A step-wise progression is specified in the modeling plan, which builds from empirical and analytical models to greater levels of modeling complexity should specific questions related to environmental risks or remedial alternatives cannot be answered by statistical and analytical calculations using the empirical data collected throughout the RI/FS. Phase 2 places an emphasis on the development of robust empirical and analytical models based on the collection of a thorough data set focused on characterizing the key processes influencing current and future risk at the Site. These models will reflect the understanding of the system variability and will use statistical analyses of data from a range of conditions to predict system behavior under potentially changing conditions (e.g., following implementation of a remedial action). The Phase 3 scope will build upon the considerable knowledge developed during Phases 1 and 2, and is projected to be more focused on determination of whether further analytical and/or numerical modeling are necessary to answer questions related to changes in the site conditions beyond those likely to be encountered during the three years/three phases of the RI or to support the detailed evaluation of remedial alternatives. A detailed description of proposed modeling activities related to the physical, chemical, and biological systems is provided in Appendix H (Modeling Plan) of the Phase 1 report.

3.11 Task 11 – Preparation and Submittal of Draft Phase 2 Site Characterization Report/Phase 3 Work Plan Addendum

3.11.1 Task 11A - Draft Phase 2 Site Characterization Report

At the conclusion of the Phase 2 field activities, a draft Phase 2 Report will be submitted by the Group to USEPA and NJDEP. The Phase 2 Report will review the investigative and data management activities that have been completed (Tasks 1 through 10). The Phase 2 report will expand upon the Phase 1 findings by further updating the CSMs, delineating the nature and extent of COPCs throughout the waterways and marshes in each portion of the BCSA, and assessing the status of fully responding to the study questions. The report will also include the sampling results from new media and study segments (e.g., marshes, groundwater-surface water interaction). Particular emphasis will be placed on the mechanisms governing fate, transport, and bioavailability of COPCs.

Graphical presentations of data from cores, plus any required geotechnical and geochemical parameters, will be provided for transects across the waterways and marshes. Data from cores will be used to establish a geochronological history of chemicals and other stressors, estimate sedimentation rates, further quantify loading to the BCSA from upland and tidal sources, and help identify potential sources of contamination in the BCSA. In addition, concurrently, the work on the human health risk assessment and ecological risk assessments will be advanced to subsequent management decision points.

3.11.2 Task 11B – Phase 3 Work Plan Addendum

The Group will prepare a Phase 3 Work Plan addendum. The third phase will continue a routine monitoring component and include sampling necessary to fill any data gaps and needs to complete the risk assessments, modeling, and detailed analysis of remedial alternatives, in addition to any Treatability Studies that may be necessary. Data gaps identified in the Phase 2 analysis will be addressed with proposals to address the identified data needs and fill data gaps. Sampling may include methods previously approved for Phase 1 and 2 and new methods to address conditions identified during Phase 2. Any QAPP revisions will be addressed in the addendum accordingly.

Task 11B will include submittal of the Phase 3 Work Plan addendum. This addendum will refine the study questions, identify data gaps, and will detail the proposed Phase 3 sampling program, which will collect appropriate data to evaluate remedial actions for the BCSA.

3.12 Task 12 – Phase 2 Findings and Proposed Phase 3 Work Plan Presentation

Within 14 days of submittal of the draft Phase 2 Report and draft Phase 3 Work Plan addendum, and upon USEPA's request, the Group will make a presentation to USEPA and the State on the findings of the Draft Phase 2 Report and discuss USEPA's and the State's preliminary comments associated with the Draft Phase 2 Report. The group will also provide a presentation on the proposed scope of Phase 3 activities.

3.13 Task 13 – Final Phase 2 Report and Phase 3 Work Plan Addendum

The Draft Phase 2 Report and the draft Phase 3 Work Plan addendum will be amended to reflect USEPA comments, and Final Reports will be prepared in accordance with the AOC/SOW within 30 of receipt of USEPA's comments.

3.14 Task 14 – Interim Remedial Measure Letter Report

3.14.1 Task 14A Draft Interim Remedial Measure Letter Report

The Draft Interim Remedial Measure (IRM) Letter Report will be prepared at the conclusion of Phase 2. It will summarize relevant Phase 1 and Phase 2 data and evaluate whether an Interim Remedial Measure (IRM) is appropriate for the BCSA. The analysis will take into account the risk assessments completed up to the time of the IRM evaluation. If appropriate, the report will present potential remedial options and plans to reduce human health risks. Task 14 will be completed within 30 days after submission of the Draft Phase 2 Report (Task 2 Phase 2.)

3.14.2 Task 14B – Final IRM Letter Report

The Final IRM Letter Report will be prepared based on comments received from USEPA and NJDEP and submitted in accordance with Section XI of the AOC.

SECTION 4

ECOLOGICAL RISK ASSESSMENT APPROACH

This section outlines the general approach to be used to characterize ecological risks for the BCSA. A brief overview of the proposed ERA approach is presented first followed by discussion of the type, content, and objectives of the ERA reports under Phase 2. For a detailed summary of the overall ERA approach, please refer to the April 2009 Work Plan.

4.1 Overview of the Process

The Ecological Risk Assessment (ERA) for the BCSA will follow USEPA's eight-step ERA process for Superfund (USEPA, 1997a). The ERA will also be consistent with USEPA's general framework for ERA (USEPA, 1998), as well as with other key USEPA risk assessment and related documents (USEPA, 1997b, 1999, 2001, 2003, 2004, 2005a,b,c). Results of the ERA will provide key input to both the RI, in terms of understanding potential ecological risks posed by the BCSA, and the FS, with respect to the identification and selection of remedial alternatives.

The ERA is being conducted to determine whether potential risk to ecological receptors may occur at the BCSA under current and future conditions and to identify which COPCs, exposure pathways, exposure media, and ecological receptors are associated with potential risks. Consistent with CERCLA guidelines, the ERA will focus primarily on chemical stressors. However, non-COPC stressors influence the current ecology of the BCSA, and will be considered in the ERA and elsewhere in the RI/FS process, so that COPC-related risks can be clearly distinguished and defined.

The key steps of the ERA process under the USEPA Superfund process are described in the April 2009 Work Plan. As part of the efforts to date, a screening level ecological risk assessment (SLERA) has been completed (Steps 1 and 2 of the ERA process), and a baseline ecological risk assessment (BERA) Work Plan (ERA Steps 3 and 4) and this Phase 2 work plan have been developed. The BERA Work Plan is presented as Appendix N of the Phase 1 report. Once these documents and associated standard operating procedure (SOPs) have been approved by the USEPA, Step 6 of the ERA process will begin, building on the previous work completed during the Phase 1 program. Subsequent ERA tasks as specified in the SOW for the Site are described below.

4.2 Ecological Exposure Assessment Phase 2 Tasks

An Ecological Exposure Assessment Technical Memorandum will be prepared within 60 days after receipt of the last set of validated data from the Phase 2 site characterization. This will be ERA Phase 2, Task 1 (ERA-P2-T1). The Technical Memorandum will present updated conceptual site models and an evaluation of the exposure pathways specific in the various segments of the BCSA, including consideration of any differences in the measurement and assessment endpoints that are warranted across the Site. As part of this work, data gaps will also be identified for incorporation into the Phase 3 site characterization. A draft and final Technical Memorandum may be required.

4.3 Ecological Exposure Assessment Phase 3 Tasks

A draft BERA Report will be submitted within 90 days of the submission of the Phase 3 Report. This will be ERA Phase 3, Task 1 (ERA-P3-T1). Potential ecological risks will be identified and characterized in accordance with CERCLA, the NCP, and USEPA guidance.

The BERA will characterize the potential ecological risks posed by the BCSA, the receptors that are at risk, the COPCs that are driving that risk, and the segments or areas of the BCSA that have varying risk profiles. Multiple lines of evidence will be used to assess risks. Additionally, the BERA report will present updated CSMs and evaluations of the exposure pathways, receptors and endpoints that are specific to the various segments of the BCSA.

The BERA will include the following analyses:

- **Hazard Identification (sources).** Available information on the hazardous substances present at the site will be reviewed and the major contaminants of concern will be selected based on their intrinsic toxicological properties.

- **Conceptual site models.** Based on contaminant identification, exposure assessment, toxicity assessment, and risk characterization, respondents will develop conceptual models of the Site.

- **Characterization of the BCSA and potential receptors.** The environmental exposure pathways for the major segments of the BCSA will be identified and characterized.

- **Select chemicals, ecologically-relevant receptor species, and endpoints.** The following will be selected: representative chemicals, ecologically-relevant species (several species which are present in BCSA and urban reference areas) and are ecologically-relevant based on dominance, keystone species status, ecotypes, and/or sensitivity to environmental contaminants), and endpoints on which to concentrate.

- **Exposure assessment.** The exposure assessment will identify the magnitude of actual or potential environmental exposures, the frequency and duration of these exposures, and the routes by which receptors are exposed. The exposure assessment will include an evaluation of the likelihood of such exposures occurring and will provide the basis for the development of acceptable exposure levels. Reasonable maximum estimates and the central tendency of exposure will be developed for both current and potential future land use, hydrology, and sediment transport conditions at the BCSA.

- **Toxicity assessment/ecological effects assessment.** The toxicity and ecological effects assessment will address the types of adverse environmental effects associated with chemical exposures, the relationships between magnitude of exposures and adverse effects, and the related uncertainties for contaminant toxicity.

- **Risk characterization.** During risk characterization, chemical-specific toxicity information will be combined, as appropriate, with quantitative and qualitative information from the exposure assessment on the measured levels of contaminant exposure or the levels predicted through environmental fate and transport modeling. These comparisons shall determine whether concentrations of contaminants at or near the BCSA are affecting or could potentially affect ecological receptors at a community or population level (or, for endangered and threatened species, at an individual level). The risk characterization shall use a weight-of-evidence approach to assess population-level risks and risks to individuals of special protection species associated with BCSA contaminants.

- **Additional studies.** The evaluation will consider the potential utility of additional studies in the laboratory or field designed to refine estimates of population-level risks for key receptors for which uncertainties are relatively large. Studies will be proposed to USEPA for review and approval in accordance with the Settlement Agreement.

- **Identification of limitations/uncertainties.** The critical assumptions (e.g., background/reference area concentrations and conditions) and uncertainties in the report will be identified and discussed.

A draft and final BERA report will be submitted for USEPA review.

SECTION 5

HUMAN HEALTH RISK ASSESSMENT APPROACH

This section outlines the general approach to be used to characterize human health risks for the BCSA. A brief overview of the proposed human health risk assessment (HHRA) approach is presented first, followed by a discussion of the content and objectives of the HHRA under Phase 2. For a detailed summary of the overall HHRA approach, please refer to the April 2009 Work Plan.

5.1 Overview of Process

The HHRA for the BCSA will follow USEPA guidance for conducting human health risk assessment at Superfund sites, including but not limited to USEPA 1989; 1990; 1991a, b; 1992a, b, c, d; 1993; 1997a; 2007; 2009. The HHRA is being conducted to determine whether potential risks to people may occur under current and future use conditions, and to identify which COPCs, exposure pathways, and exposure media are associated with potential risks. The results of the HHRA evaluation will provide key input to both the remedial investigation, in terms of understanding potential human health risks, and the subsequent risk analysis of remedial alternatives in the FS, with respect to the identification and selection of remedial alternatives for protection of human health. The HHRA will be updated and refined throughout all three phases of the RI as new information increases our understanding of the BCSA and the type and magnitude of potential human exposures.

5.2 Risk Assessment Phase 2 Tasks

An updated Pathways Analysis Report (PAR) will be prepared and submitted within 60 days after receipt of the last set of validated data from the Phase 2 site characterization. The updated PAR will build on the Memorandum on Exposure Scenarios and Assumptions, the Phase 1 PAR, and validated data from the Phase 2 report. The updated PAR will include components as described above. The results of this analysis will be used in the risk evaluation of Interim Remedial Measures (IRM) analysis and letter report.

5.3 Risk Assessment Phase 3 Tasks

5.3.1 Task 1 – Updated Pathway Analysis Report

Following completion of Phase 3, the PAR will be updated within 60 days after receipt of the last validated data. The updated PAR will be reviewed and approved by USEPA prior to the submission of the draft BHHRA. The PAR will build on the Memorandum on Exposure Scenarios and Assumptions, the Phase 2 PAR, and validated data from the Phase 3 report, and will include components as described above.

5.3.2 Task 2 – Draft Baseline Human Health Risk Assessment

Within 90 days of the completion of the Phase 3 data collection or USEPA's approval of the PAR, whichever is later, a Draft BHHRA will be submitted to USEPA for inclusion in the RI. The submittal will include completed RAGS Part D, Tables 1 through 10 summarizing the calculated cancer risks and noncancer hazards with a discussion of uncertainties and critical assumptions (e.g., background concentrations and conditions). The BHHRA will be prepared in accordance with the approach and parameters described in the approved Memorandum of Exposure Scenarios and Assumptions and the PAR described above. Text and tables from these previously approved reports will be included in the appropriate sections of the BHHRA.

5.3.3 Task 3 – Final Baseline Human Health Risk Assessment

A final BHHRA will be prepared following receipt of written comments from USEPA. If USEPA disapproves of or requires revisions to the Draft BHHRA, in whole or in part, a revised BHHRA will be revised that is responsive to USEPA's written comments.

SECTION 6

FEASIBILITY STUDY APPROACH

6.1 Introduction

The FS will present a stepwise, iterative, and comprehensive evaluation of remedial options for achieving the remedial action objectives (RAOs) for the BCSA. This will be done through a process that lays the groundwork for proposing and selecting a remedy that best reduces or controls risks to human health and the environment consistent with the national contingency plan (NCP) remedy selection criteria. The BCSA FS was initiated with Phase 1 and will continue in Phase 2 and 3, to correspond with the phased approach to the RI. The FS will continue to be built on the additional site knowledge gained in Phase 2 and 3 of the RI to ensure that the feasibility evaluations reflect risk mitigation needs and are effective for the specific conditions within the BCSA watershed.

The Phase 1 FS was initiated at the end of the first year of field work and included the identification of candidate technologies and potential remedial alternatives. In Phase 2, following the second year of field work, data will be evaluated from each of the major segments of the BCSA to identify the range of technologies that may be well-suited to the conditions that dominate that particular study segment. These technologies will be screened and combined into remedial alternatives. Based on that analysis, additional data needs will be identified to support the completion of the detailed analysis of alternatives, including any treatability studies. Following the third year of site characterization and possible treatability studies, the detailed analysis of remedial alternatives will be completed.

As part of the alternatives evaluation process, the process of identification and screening of alternatives will be advanced after the Phase 2 work, and with the detailed alternatives analysis after Phase 3, in a manner that is consistent with the 2005 Sediment Remediation Guidance (USEPA, 2005a).

One of the tools that may be used to semi-quantify professional opinions, and add transparency, and objectivity to the Phase 3 FS analysis, is a tabular rating system. Best professional judgment in conjunction with relevant guidance materials and literature will be used in assigning points. The rating form and numerical scoring process would be developed and presented to the USEPA as part of the Work Plan Addendum following Phase 2. It will be fashioned from other similar rating forms and approaches to comparative alternatives analysis to provide for an evaluation that is sufficiently detailed to distinguish among the alternatives. The Phase 3 detailed evaluation will include all seven of USEPA's nine evaluation criteria to be evaluated by the group. Specifically, the threshold criteria of overall protectiveness of human health and the environment and compliance with ARARs and balancing criteria of long-term protectiveness and permanence; reduction of toxicity, mobility, or volume; short term effectiveness; implementability and cost effectiveness. Particular emphasis will be put on the evaluation of the balancing criteria. In addition, combinations of alternatives, sequenced over time in an adaptive management context, will be evaluated. The results will be detailed in the and FS Report in support of the identification of recommended remedial approaches for the BCSA.

6.2 Feasibility Study Phase 2 Tasks

The focus in Phase 2 of the FS effort will be to develop and screen remedial alternatives built from viable technologies identified in the Candidate Technologies Memorandum (CTM).

The Group shall supplement the RI/FS Guidance (USEPA, 1988) with materials such as Sediment Guidance (USEPA, 2005a).

6.2.1 Task 1 – Development and Screening of Remedial Alternatives

The initial Phase 2 FS effort will be the development and screening of remedial alternatives. This work will build upon the CTM and the findings of RI Phases 1 and 2 (e.g., fate and transport analysis, modeling (to the extent warranted) and risk assessment (especially exposure pathways analysis)) and take into account any actions taken or being evaluated based on the IRM letter report. In accordance with the SOW, the objective of this task will be to develop and evaluate a range of risk management options that at a minimum ensure protection of human health and the environment.

The AOC SOW recognizes that the BCSA should be approached on a watershed basis. Accordingly, alternatives will entail a combination of technologies applied in an adaptive management approach with a monitoring component to assess effectiveness. Development of long-term monitoring aspects of the remedial alternatives will be prepared in accordance with the USEPA's Sediment Guidance (USEPA, 2005a). Remedial alternatives will consider the future use concepts of the New Jersey Meadowlands Master Plan.

This work will commence with the delivery of validated data from Phase 2 of the RI, in accordance with the schedule shown in Section 7and will include the various subtasks identified in the SOW.

6.2.2 Task 2 – Development and Screening of Remedial Alternatives Technical Memorandum

Within 30 days after USEPA's approval of the Phase 2 RI Report, the Group will submit a draft Technical Memorandum summarizing the work performed in and the results of FS tasks from both Phases 1 and 2 (described above). The memorandum will document the methods, rationale, and results of the alternatives screening process. The memorandum will also summarize the reasoning employed in screening, ranking, arraying alternatives that remain after screening, and identifying the action-specific ARARs for the alternatives that remain after screening. The memorandum will address whether treatability studies are required.

If required by USEPA's comments, the Group will modify these remaining alternatives to assure that a complete and appropriate range of viable alternatives are identified and considered in detailed analysis. The Technical Memorandum will document the methods, rationale, and the results of the alternatives screening process and any decisions on treatability studies.

6.2.3 Task 3 – Presentation to USEPA and State

Within 30 days after USEPA's approval of the Phase 2 RI Report, and upon USEPA's request, the Group will make a presentation identifying the RAOs and summarizing the development and preliminary screening of remedial alternatives and recommendations regarding treatability studies.

6.3 Feasibility Study Phase 3 Tasks

The FS Phase 3 efforts will utilize the information from the three RI phases, the Baseline Risk Assessment and treatability or pilot studies conducted in the BCSA, to conduct a detailed analysis of the remaining potential remedial alternatives. The detailed analysis will be conducted in conformance with CERCLA guidance (USEPA, 1988) and USEPA Sediment Guidance (USEPA, 2005a). The evaluation will draw upon recent studies on the success and efficacy of sediment remediation efforts conducted by the National Academies (National Academies, 2007) and USACE (USACE, 2008). Section 11 of the RI/FS Work Plan (Geosyntec, 2009) describes the Phase 3 FS tasks.

SECTION 7

SCHEDULE

The current project schedule is presented as a Gantt chart in Figure 7-1. The project tasks are shown by overarching activity (e.g., Remedial Investigation) and by phase. In general, the remaining phases are defined as follows:

- **Phase 2.** The summer season dependent Phase 2 RI field work was completed in the Summer of 2010. Reporting will occur throughout 2011 via a series of work sessions with the USEPA. Hydrodynamic studies, high resolution sediment sampling, sediment stability, sediment flux, surface water, and air monitoring work will occur throughout 2011 to correspond to seasonal and storm event criteria for the sampling. In addition, a Baseline Monitoring Work Plan (BMWP) will be developed and submitted in the winter of 2011 and scheduled for implementation in 2011. This BMWP was suggested by the Contaminated Sediment Advisory Group (CSTAG) and will build off of the Phase 1 and Phase 2 monitoring data collected to date. In addition, the FS and risk assessment efforts associated with Phase 2 will occur throughout 2011 and into 2012. The Phase 2 Report will incorporate both Phase 1 and Phase 2 findings, consistent with the responses to the Phase 1 comments and the discussions during work sessions in 2011. The submission of the Phase 2 report is anticipated in the spring of 2012, along with or followed by the Phase 3 Work Plan Addendum/QAPP/FSP.

- **Phase 3.** Phase 3 field work will commence in the summer of 2012 and its completion and reporting will be determined by the scope of work needed to address each of the Study Questions and to complete the risk assessment and the alternatives analysis. FS Phase 3 activities will begin on a schedule dependent upon completion of RI activities and any treatability studies or pilot studies that may be conducted.

Noteworthy points regarding the schedule include the following:

1. Certain RI field tasks involve collecting data over tidal cycles. Accordingly, although these tasks are shown over an extended period, the effort will not be continuous.

2. The RI includes tasks that will obtain trend data such as collecting hydrodynamic data with Moored Hydrodynamic/Water Quality Stations. These efforts will extend beyond Phase 2. In the schedule, these tasks are shown ending at the time the final Phase 2 report is submitted. For example, RI Phase 2 Task 1 Hydrology/ Hydrodynamics/Transport (RI-P2-T1) will extend beyond a specific work phase.

3. The RI includes tasks that involve quarterly and semi-annual activities. Similar to the trend data noted above, the sampling events to be included in the Phase 2 report will be suspended

nominally at the end of the Phase 2 general field effort to allow for data validation and inclusion of results in the Phase 2 report. The data collection will continue on the schedule and the additional data (beyond that reported in the Phase 2 summary report) will be submitted under separate cover. This data will be discussed with the USEPA RPM during sampling planning and scheduling.

4. Field events are weather dependent. Adjustments to the more detailed schedule will be necessary to accommodate weather conditions, which the Project Coordinator will discuss with the USEPA RPM.

5. Certain RI events are tied to covering a range of storm conditions. These events in particular are weather dependent and will require flexibility in the schedule.

6. The significant work involved in the RI, risk assessments, and FS will require an aggressive and dedicated effort of all parties involved. The field effort, data validation and evaluation, writing, review, and approval of the report and associated risk assessment and FS efforts of a given phase will run until nearly the start of the next phase. Advance planning to meet the schedule will be important to complete the work in the projected time frame.

7. The schedule for Phase 2 includes estimated times for USEPA review of Group-prepared deliverables. Generally, the Group has assumed a 45 (calendar)-day Agency review and comment period for the draft of a major deliverable, followed by a 30-day effort to respond to comments and revise the deliverable. It is the Groups intent to mobilize late July 2010 to begin Phase 2 activities on or around July 26, pending USEPA approvals.

8. The scope of work may need to be augmented at times based on the ongoing data analysis, risk assessment, and alternatives analysis. Such adaptive adjustments would be focused on assessing specific questions needed to support risk analysis and remedy selection.

SECTION 8

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Table 3-1 RI/FS Work Plan Task Numbering System

REMEDIAL INVESTIGATION (RI)
Phase 1 RI/FS - Hydrodynamic Studies/Horizontal COPC Delineation (RI-P1)
Task 1 - Hydrology/Hydrodynamics/Sediment Transport (RI-P1-T1)
Task 2 - Surface Water Investigation (RI-P1-T2)
Task 3 - Sediment Investigation (RI-P1-T3)
Task 4 - Groundwater Investigation (Desktop Study) (RI-P1-T4)
Task 5 - Atmospheric Deposition Data Review (RI-P1-T5)
Task 6 - Biota Investigation (RI-P1-T6)
Task 7 - Cultural Resources Phase 1A Assessment (RI-P1-T7)
Task 8 - Reference Site Evaluation (RI-P1-T8)
Task 9 - Data Management/Data Validation (RI-P1-T9)
Task 10 - Prepare Modeling Plan (RI-P1-T10)
Task 11 - Draft Phase 1 Report/Phase 2 Work Plan Addendum (RI-P1-T11)
Task 12 - Phase 1 Findings Presentation (RI-P1-T12)
Task 13 - Final Phase 1 Report/Phase 2 Work Plan Addendum (RI-P1-T13)
Phase 2 RI/FS - Additional COPC Delineation (RI-P2)
Task 1 – Evaluation of Site Hydrology/Hydrodynamics/Sediment Transport (RI-P2-T1)
Task 2 – Surface Water Investigation (RI-P2-T2)
Task 3 – Sediment Investigation (RI-P2-T3)
Task 4 – Surface Water/Groundwater Interactions (RI-P2-T4)
Task 5 – Biota Investigation and Human Activity Assessment (RI-P2-T5)
Task 6 – Reference Site Evaluation (RI-P2-T6)
Task 7 – Atmospheric Deposition and Air Monitoring (RI-P2-T7)
Task 8 – Regional Background Data Review (RI-P2-T8)
Task 9 – Data Management/Data Validation/Field Audits (RI-P2-T9)
Task 10 – Modeling (RI-P2-T10)
Task 11 – Preparation and Submittal of Draft Phase 2 Site Characterization Report/ Phase 3 Work Plan Addendum (RI-P2-T11)
Task 12 – Phase 2 Findings and Proposed Phase 3 Work Plan Presentaton (RI-P2-T12)
Task 13 – Final Phase 2 Report and Phase 3 Work Plan Addendum (RI-P2-T13)
Task 14 – Interim Remedial Measure Letter Report (RI-P2-T14)
Phase 3 RI/FS - Final Site Characterization (RI-P3)
Task 1 - Phase 3 Field Characterization (RI-P3-T1)
Task 2 - Draft Phase 3 Site Characterization Report (RI-P3-T2)
Task 3 - Phase 3 Findings Presentation (RI-P3-T3)
Task 4 - Final Phase 3 Report (RI-P3-T4)
(To be expanded/revised by Phase 2 Findings)

Table 3-1 RI/FS Work Plan Task Numbering System

RISK ASSESSMENT - (HHRA & ERA)
Phase 1 HHRA - Exposure Scenarios and Assumptions and Pathways Analysis (HHRA-P1) Task 1 - HHRA - Draft Exposure Scenarios and Assumptions Tech. Memo. (HHRA-P1-T1) Task 2 - Final Memorandum on Exposure Scenarios and Assumption Memo (HHRA-P1-T2) Task 3 - Pathways Analysis Report (HHRA-P1-T3) Task 4 - Final Par (HHRA-P1-T4) **Phase 1 ERA - Ecological Risk Assessment (ERA-P1)** Task 1 - Screening-Level Ecological RA (Incl. in Phase 1 Report) (ERA-P1-T1) Task 1 - BERA Work Plan (Included in Phase 2 Work Plan addendum) (ERA-P1-T2)
Phase 2 HHRA - Updated Pathways Analysis (HHRA-P2) Task 1 - Updated Pathways Analysis Report (HHRA-P2-T1) **Phase 2 ERA - Ecological Exposure Assessment (ERA-P2)** Task 1 - Ecological Exposure Assessment Technical Memorandum (ERA-P2-T1)
Phase 3 HHRA - HHRA Report (HHRA-P3) Task 1 - Updated Pathways Analysis Report (HHRA-P3-T1) Task 2 - Draft HHRA Component of the Phase 3 Report (HHRA-P3-T2) Task 3 - Final HHRA (HHRA-P3-T3) **Phase 3 ERA - BERA Report (ERA-P3)** Task 1 - Baseline Ecological Risk Assessment Report (BRA-P3-T1)

Table 3-1 RI/FS Work Plan Task Numbering System

FEASIBILITY STUDY (FS)
Phase 1 FS - Identification of Candidate Technologies (FS-P1)
Task 1 - Draft Ident. of Candidate Tech. & Potential Remedial Alts. Memo (FS-P1-T1)
Task 2 - Revised CTM (FS-P1-T2)
Phase 2 FS - Development and Screening of Alternatives (FS-P2)
Task 1 - Development and Screening of Remedial Alternatives (FS-P2-T1)
Task 1A - Develop General Response Actions (FS-P2-T1A)
Task 1B - Identify areas or volumes of media (FS-P2-T1B)
Task 1C - Assemble and document alternatives (FS-P2-T1C)
Task 1D - Refine alternatives (FS-P2-T1D)
Task 1E - Conduct & document screening each alternative (FS-P2-T1E)
Task 2 - Screening of Remedial Alternatives Technical Memorandum (FS-P2-T2)
Task 3 - Present to USEPA & NJDEP (FS-P2-T3)
Phase 3 FS - Detailed Analysis of Alternatives and FS Report (FS-P3)
Task 1 - Detailed Analysis of Remedial Alternatives (FS-P3-T1)
Task 1A - Apply Seven Criteria and document analysis (FS-P3-T1A)
Task 1B - Compare alternatives and document (FS-P3-T1B)
Task 1C - Present to USEPA & NJDEP (FS-P3-T1C)
Task 2 - Treatability Studies (If Required) (FS-P3-T2)
Task 3 - Draft Feasibility Study Report (FS-P3-T3)
Task 3A - Prepare Draft Feasibility Study Report (FS-P3-T3A)
Task 3B - Present Findings of Draft FS to USEPA/NJDEP (FS-P3-T3B)
Task 4 - Respond To USEPA Comments on the Draft FS Report (FS-P3-T4)
Task 5 - Final Feasibility Study Report (FS-P3-T5)

Table 3-2 Phase 2/Task 1 - Evaluation of Hydrology/Hydrodynamics/Sediment Transport

Sub Task Number/Name	Rationale	Number/Location	Analytical Parameters
Task 1A			
Moored Hydrodynamic and Water Quality Monitoring Stations	Collect hydrodynamic and turbidity data in support of chemical and particulate fate and transport. Characterize suspended particulates. Evaluate exchange with Hackensack River and along study segments within BCSA. Assess marsh/waterway exchange. Collect water quality data to evaluate the system's physiochemical characteristics. Evaluate influence of discharge from NJSEA outfall.	5 moored stations; 2 temporary moored stations for ~ 1-month long deployment for NJSEA discharge event monitoring.	Velocity Profile (ADV/ADCP) Temperature pH Salinity Dissolved Oxygen Oxidation/Reduction Potential Turbidity Chlorophyll-a LISST particle size distribution
Task 1B.01			
Storm Surge Transect Monitoring	Collect velocity, turbidity, salinity, and temperature data along channel transects to quantify water and sediment flux and develop a correlation for extrapolate flux estimates from long-term monitoring data. Collect suspended particle size distribution data. Collect TSS samples to relate turbidity and acoustic backscatter data to suspended solids concentrations.	Measurement of transect velocity, water quality, and particle size during two storm surge events for up to 4 days. Measurements taken as frequently as feasible and safe during daylight hours. Transect TSS samples collected during a subset of the transect velocity and water quality measurements.	Velocity Profile Turbidity Salinity and Temperature LISST Particle Size Distribution Profiles TSS
Task 1B.02			
Waterway Pool Transect Monitoring	The deep pools present at many of the waterway meanders are significant features relative to the typical channel morphology. The series of transect measurements will provide a characterization of the vertical profile of water velocity across the channel transect at the waterway pools under conditions ranging from low to high tide.	Transect monitoring consisting of velocity measurements will be performed across a channel transect at the three waterway pools	Velocity Profile
Task 1C			
Suspended Solids Characterization	Routine collection of concurrent and co-located TSS samples and turbidity measurements to develop a TSS/NTU calibration curve that addresses seasonal variations in water column composition.	Collection of TSS samples and measurement of turbidity levels every other month at each of the moored stations during four points in the tidal cycle.	Total Suspended Solids Particulate Organic Carbon Dissolved Organic Carbon Total Organic Carbon
Task 1D			
Dye Tracer Study	Evaluate hydraulic connection of various features of the BCSA. Specific objectives: evaluate tidal exchange of UBC, assess water exchange with the marshes, and assess hydraulic connection of LBC with the rest of BCSA.	Two dye studies will be completed. Dye will be injected under spring and neap tide conditions at UBC. Select moored stations will be equipped with a dye fluorescence sensor and mobile measurements made with a boat-deployed sensor. Discrete samples will be collected throughout system from a boat for laboratory florescence analysis. Each study will have a duration of 3-4 days.	Field Fluorescein Measurements Laboratory Fluorescence Analysis
Task 1E			
High Frequency Monitoring of Sediment Bed Flow Velocities and Suspended Solids	High frequency ADV measurement at the sediment bed to quantify near bed turbulance and sediment dynamics, particle settling speeds, and concentration as a function of tidal velocities.	Deployment of an ADV in three marsh tributaries and six main waterway locations to measure near bed dynamics over a 24-hr tidal cycle. Three main channel locations will be subtidal and three will be intertidal.	Velocity Measurement (ADV)

Table 3-2 Phase 2/Task 1 - Evaluation of Hydrology/Hydrodynamics/Sediment Transport

Task 1F			
Monitoring of Upland Freshwater Inputs	Long-term quantification of water depths to estimate flow rates at six storm water outfall/drainage ditches. Measurement of turbidity and other water quality parameters during 2 storm surge events (coincides with Task 1B).	Installation of pressure transducers at six outfall/drainage locations for the duration of P2. Monthly download of data. Measurement of outfall/drainage physical dimensions. Periodic measurement of flow velocity and sample collection for TSS, POC, and DOC during surge events. Temporary deployment of a YSI multimeter at each location to quantify water quality parameters during two storm surge events.	Water depth Temperature pH Salinity Dissolved Oxygen Turbidity Flow velocity Total Suspended Solids Total Organic Carbon Particulate Organic Carbon
Task 1G			
Sedflume	Sedflume testing of sediment cores to further characterize the stability of the sediments at the BCSA Site	Collection of cores from 12 locations and onsite testing using a Sedflume to assess the shear stress required to erode sediments as a function of sediment depth. Collection of samples for geotechnical characterization across the core profile.	Sediment erosion rates as a function of shear stress Sediment bulk density Sediment particle size Sediment organic content Sediment mineralogy Sediment gas content

Table 3-3 Phase 2/Task 2 - Surface Water Investigation

Sub Task Number/Name	Rationale	Number/Location	Analytical Parameter
Task 2A - Routine Monitoring			
Task 2A.01			
Automated Sampling	Time-integrated 2-week composite samples (spring-neap); Representative flood and ebb tide concentrations. ISCO sampler intakes correspond to YSI intakes; for stations MHS-01 and MHS-06, ISCO intakes correspond to deep YSI intake (change from Phase 1)	5 locations for 2 events (Summer and Fall); Paired with moored hydrodynamic locations	Unfiltered TAL metals (including mercury), Unfiltered polychlorinated biphenyls, TOC, Ammonia
Task 2A.02			
Manual Sampling	"Snapshot" concentrations; Broader spatial coverage and more analytical analyses	37 Locations 2 events, Summer and Fall on schedule with Task 2A.01	**COPCs:** Methyl Mercury (unfiltered and filtered), Mercury (unfiltered and filtered), Polychlorinated biphenyls (unfiltered and filtered), TAL Metals (unfiltered and filtered), Field Parameters** **Non-COPCs (10 to 20% of samples):** Above list plus: Volatile Organic Compounds (unfiltered), Semivolatile Organic Compounds (unfiltered), Pesticides (unfiltered), Nutrients/Conventional Parameters*, Field Parameters**, Cyanide Full Cation/Anion analysis for LBC Only
Task 2A.03			
Automated Storm Event Sampling	Better understand the effects of storms on COPC concentrations and transport. Evaluate both general storm and storm surge events.	5 autosamplers at moored stations and 5 autosamplers in tributary locations; sampled during 2 storm events in waterways and 4 in tributaries. See FSP for sampler allocation and precise timing/sample number during storms.	Unfiltered TAL metals (including mercury), Unfiltered polychlorinated biphenyls, TOC, Ammonia
Task 2A.04			
Manual Stormwater Sampling	Broader coverage and analytical analyses during a single storm event; Better understanding of effects of storm events on COPC concentrations and transport	20 of 37 manual locations system-wide (1 time event)	**COPCs:** Methyl Mercury (unfiltered and filtered), Mercury (unfiltered and filtered), Polychlorinated biphenyls (unfiltered and filtered), TAL Metals (unfiltered and filtered), Field Parameters** **Non-COPCs (10 to 20% of samples):** Above list plus: Volatile Organic Compounds (unfiltered), Semivolatile Organic Compounds (unfiltered), Pesticides (unfiltered), Nutrients/Conventional Parameters*, Field Parameters**, Cyanide

Table 3-3 Phase 2/Task 2 - Surface Water Investigation

Sub Task Number/Nam	Rationale	Number/Location	Analytical Parameter
Task 2B - Phase 2 Specific			
Task 2B.01			
Marsh - Waterway COPC Exchange	Quantify sediment and dissolved COPC flux into and out of marshes through automated sampling of tributaries through which flooding and ebbing of marshes takes place; time-integrated 2-week composite samples	Groupings (each containing 3 ISCO automated samplers) will be placed in: Nevertouch Marsh Eight Day Swamp Walden Swamp (2 separate, time-integrated Ebb/Flow composite samples) Summer and Fall sampling on schedule with Task 2A.01	Unfiltered TAL metals (including mercury), Unfiltered polychlorinated biphenyls, TOC, Ammonia, TSS (note 3 TSS samples in series required over 14-day period to address hold time requirements.)
Task 2B.02			
Marsh Intertidal Pool Sampling	Obtain preliminary understanding of chemical concentrations within marsh pools	6 locations, each sampled in two events (Summer and Fall) Summer and Fall sampling on schedule with Task 2A.01	Methyl Mercury (unfiltered and filtered), Mercury (unfiltered and filtered), Polychlorinated biphenyls (unfiltered and filtered), TAL Metals (unfiltered and filtered), Volatile Organic Compounds (unfiltered), Semivolatile Organic Compounds (unfiltered), Pesticides (unfiltered), Nutrients/Conventional Parameters*, Field Parameters**, Cyanide
Task 2B.03			
COPC Fractionation	COPC flux is an important component of evaluating the net sediment and COPC transport. Understanding the distribution of COPCs on differeing particle sizes will support understanding of transport mechanisms.	3 locations at 2 different periods of tidal cycles (mid-flood, high slack tides). 2 sampling events (1 warm weather, 1 cold weather.) Filtration on one filter size per parameter.	TAL Metals PCBs Methyl Mercury TSS TOC/POC/DOC
Task 2B.04			
Storm Surge Surface Water Sampling	COPC and suspended sediment exchange during storm surge events may differ from those of more typical conditions. Program includes high-frequency collection of manual samples for COPCs and TSS during surge events.	2 storm surge events. For each event, sampling at MHS-01 (6 XZ stations) and MHS-06 (4 XZ stations). Up to 4 sample sets for each of rising and falling limb of each surge. Sampling feasibility/completeness contingent upon surge timing and safety considerations.	TAL Metals (unfiltered) Mercury (unfiltered) PCBs (unfiltered) TSS

*List includes nitrate/nitrite, sulfate/sulfide, phosphate, chloride, ammonia, alkalinity, total suspended solids, dissolved organic carbon, particulate organic carbon, total organic carbon, biochemical oxygen demand, chemical oxygen demand

** List includes: pH, salinity, specific conductance, turbidity, dissolved oxygen, oxidation/reduction potential, temperature, velocity
COPCs = TAL metals, total mercury and methyl mercury, PCBs

Table 3-4 Phase 2/Task 3 - Sediment Investigation

Sub Task Number/Name	Rationale	Number/Location	Analytical Parameters
Task 3A			
Low-Resolution Waterway Sediment Core Sampling	Obtain understanding COPC distribution in top 60 cm. Develop information germane to remedial technologies evaluation.	31 locations (0 to 60 cm): 3 horizons each 13 geotechnical samples 5 column settling test samples (co-located with the 5 of the 13 geotechnical samples)	COPCs on 86 of 93 samples and sulfate, sulfide, TOC Full List on 7 of 93 samples (see Figures 3-8 and 3-9) Column setting test (USACE, 2003) for 5 areas of highest COPC levels. - TSS on column supernatant in accordance with USACE protocol. - Full list plus TCLP, sulfate/sulfide, and salinity on settled solids. Effluent Elutriate Test (USACE, 2003) for same 5 sample locations - Full list plus Nutrients/Conventional Parameters on effluent elutriate Geotechnical analysis including Atterberg limits, U-U triaxial, moisture content, grain size, and LOI on 13 samples; field vane shear on 5 samples.
Task 3B			
Supplementary BAZ Sediment Sampling	Assess the general distribution of COPCs in sediments most accessible to organisms.	37 locations 0 to BAZ bottom	Full List on 9 samples (see Figures 3-8 and 3-9) COPC's on all samples and sulfate, sulfide, TOC
Task 3C			
Sediment Surface Investigation for Correlation to Biota COPC Residues	Assess COPC Concentrations in the shallow oxygenated zone of the sediment column to support a more precise understanding of correlations between COPC concentrations in sediment and mummichog	20 Locations in UBC (0 to 2.5 cm) 20 Locations in LBC (0 to 2.5 cm)	Mercury, methyl mercury and PCBs TOC, sulfate, sulfide, AVS/SEM
Task 3D			
Marsh Sediment Sampling: COPCs	Gain understanding of COPC distribution in marsh sediments accessible to ecological receptors of interest as well as sediments at depth.	54 marsh locations: - 12 locations (0 to 50 cm) with 4 horizons each (0 to 5 cm, 10 to 15 cm, 15 to 25 cm, 35 to 50 cm) - 42 locations (0 to 15 cm) with 2 horizons each	Full List on 10% of samples COPCs on 90% of samples and sulfide, sulfate, TOC
Marsh Sediment Sampling: Methylation/Demethylation Study	Detailed assessment of factors that potentially control mercury methylation/demethylation process.	24 marsh locations: mercury methylation/demethylation study - 8 horizons, 2 cm (0 to 16 cm)	Total mercury Methyl mercury pH/Redox (field) Sulfide/Sulfate TOC Salinity (in water) Biodegradable dissolved organic carbon (6 cores with 4 horizons per core) AVS/SEM
Marsh Sediment Sampling: Geochronology	Characterize age distribution of marsh sediments and deposition rates.	Geochronology: 10 locations (0 to 38 cm) with 12 horizons each (3 and 4 cm horizons: 10 3-cm horizons from 0 to 30 cm, 2 4-cm horizons from 30-38 cm) (Co-located with the 10 of the 12 (0 to 50 cm) cores)	Geochronology (^{210}Pb, ^{137}Cs), Streamlined Grain Size Analysis (Loss on Ignition and Single Sieve Wash)
Marsh Sediment Sampling: Geotechnical/FS Testing	Collect information germane to remedial technologies evaluation.	13 root mat locations and 5 below the root mat locations	Geotechnical - root mat: (13 samples): Moisture Content, Grain Size Geotechnical below root mat: (5 sample locations) Atterberg Limits, Moisture Content, Field Vane Shear, Loss on Ignition, Grain Size Other FS-Related: (3 marsh root mat locations): Effluent elutriate test

Table 3-4 Phase 2/Task 3 - Sediment Investigation

Sub Task Number/Name	Rationale	Number/Location	Analytical Parameters
Task 3E			
Phragmites Sampling	Better understand the exchange of sediment and COPCs between the waterways and the marshes. Evaluate the potential exposure point concentrations in marsh invertebrate/insect habitats. Evaluate potential exposure point concentrations for mammals in the marsh system.	10 samples from each of the following media (all co-located) - Phragmites leaves (living) - Recently dead and decaying coarse material from the base of the plants - The detritus layer just above the root zone sediments - *Phragmites* roots	COPCs Stable Isotopes (C, N, S) TOC COPCs (roots)
Task 3F			
Waterway High-Resolution Sediment Core Sampling	Document to a high degree of vertical precision sediment geochronology, deposition rates, and natural recovery pattern	7 coring locations: - Advanced to 1 m, with additional 1-2 m depth core section collected and archived - 0-1 m section subsampled on 2 cm horizons - Initial samples include 0-12 cm on 2 cm horizons, then 14-16 cm, 18-20 cm, 22-24 cm, … 98-100 cm analyzed; remaining horizons archived	Mercury, PCBs, ^{137}Cs, ^{210}Pb, Streamlined Grain Size Analysis (Loss on Ignition and Single Sieve Wash) ^{7}Be on 0-6 cm samples Methylmercury on 0 to 20 cm samples.

Notes:

COPCs = TAL metals, total mercury and methyl mercury, PCBs
Full List = COPCs + AVS/SEM, volatile organic compounds, semi volatile organic compounds, pesticides, biochemical oxygen demand, chemical oxygen demand, grain size distribution, cation exchange capacity, percent moisture

Table 3-5 Phase 2/Task 4 - Groundwater/Surface Water Interactions

Sub Task Number/Name	Rationale	Number/Location	Analyses
Task 4A			
Marsh Interflow Characterization	Quantify hydrologic properties (gradient, hydraulic conductivity) of marsh subsurface. Quantify COPC concentrations in marsh interflow/groundwater. Establish redox conditions of marsh subsurface.	Three well clusters will be placed in 3 marshes (9 total) and will be completed at depth horizons of 15 - 46 cm and 46-91 cm. Each well will be slug tested to estimate the hydraulic conductivity of the marsh sediments. Water levels and water quality will be evaluated summer and fall.	Methyl Mercury (total and filtered) Trace Mercury (total and filtered) TAL Metals (filtered and unfiltered) Cyanide Nutrients/Conventional Parameters* Field Parameters** Hydraulic conductivity Hydraulic gradient Major cations and anions First Quarter Sampling Only: Polychlorinated biphenyls (unfiltered)
Task 4B			
Focused Sampling of Groundwater Discharge from Landfills	Quantify the flux of groundwater and associated COPCs from landfills to the BCSA waterways.	Seven wells will be installed at selected locations in the landfills in LBC to allow for sampling of COPCs. Each well will be slug tested to estimate the hydraulic conductivity of the marsh sediments. Water levels and water quality will be evaluated summer and fall. Each well will be screened at one horizon.	Methyl Mercury (total and filtered) Trace Mercury (total and filtered) TAL Metals (filtered and unfiltered) Cyanide Semi-Volatile Organic Compounds Volatile Organic Compounds Nutrients/Conventional Parameters* Field Parameters** Hydraulic conductivity Hydraulic gradient Salinity Major cations/anions First Quarter Sampling Only: Polychlorinated biphenyls (unfiltered) Pesticides (unfiltered)

* List includes: nitrate/nitrite, sulfate/sulfide, phosphate, chloride, ammonia, alkalinity, total suspended solids, dissolved organic carbon, total organic carbon, biological oxygen demand, chemical oxygen demand

** List includes: pH, salinity, specific conductance, turbidity, dissolved oxygen, oxidation/reduction potential, temperature

Table 3-6 Phase 2/Task 5 - Biota Investigation Human Activities

Sub Task Number/Name	Rationale	Number/Location	Analyses
Task 5A			
COPC residues in the BCSA food web	Understand the magnitude and variability in COPC tissue residues. Refine BCSA CSMs.	67 biota locations throughout system: 67 sampled for Mummichog; 24 for White Perch (Whole body and fillet composite at each location) and Blue Crab (Muscle tissue and carcass at each location, hepatopancreas for 12); 12 for Fiddler Crab (Whole body)	Total Trace Mercury Methyl Mercury PCBs Lipids % Moisture
Task 5B			
Survey of human activity patterns in the BCSA	Characterize human activity in the BCSA to support a site-specific evaluation of potential human exposures in the BCSA.	Direct observations (during field work); camera surveys	Number of visitors; visit duration; type of activity; frequency of visits; harvest gear
Task 5C			
Fish Community Survey	Characterize and compare fish communities.	4 trawling stations in each segment; 3 gill net stations in each segment; 20 minnow traps in each segment; 3 water quality stations in each segment; 4 segments sampled throughout system	Comparisons between segments of water quality parameters (temperature, dissolved oxygen, salinity) and fish community metrics (relative species abundance, richness, evenness, diversity)
Task 5D			
Food Web Study/Fish Dietary Analysis	Understand trophic relationships.	20 fish per species per segment targeted for visual gut content analysis: Mummichog, White Perch (juvenile and adult); dry mass analysis for one composite sample of each species in each segment	Gut content enumeration and taxonomic identification; dry mass analysis of dominant taxa in diet
Food Web Study/Stable Isotope Study	Understand trophic relationships.	Three samples from each of 4 reaches: White Perch (1) (Juvenile and Adult) Mummichog (1) Blue Crab (1), Mud Crab (3), Fiddler Crab (1) Amphipods (3) Shrimp (3) Benthic Infauna (4) Reed Grass (live and dead) (2) Marsh Detritus (2) Benthic Microalgae (5) Phytoplankton (ebb and flood tide) (5)	Stable Isotopes (^{13}C, ^{15}N, ^{34}S)
Task 5E			
Benthic Survey	Identify composition and diversity of benthic community.	5 sampling locations per segment with two samples per location (one on exposed mudflat, one in thalweg in subtidal area)	Comparison between segments of benthic invertebrate community metrics (relative species abundance, richness, evenness, diversity)
Task 5F			
Qualitative Survey of Marsh Invertebrate/Insect Community	Characterize and compare marsh invertebrate communities in space and time, evaluate collection methods.	3 marshes. 1 Light trap sample per marsh; 1 Malaise trap per marsh; 2 Vacuum samples per marsh; 1 sticky card trap in each marsh exchanged twice monthly July - Sept.	Comparison between marshes of invertebrate community metrics (relative species abundance, richness, evenness, diversity) and potential habitat niche contribution to upper trophic levels
Task 5G			
Evaluation of BCSA Marsh Production, Functions, and Values	Understand potential impact of COPCs on marshes using measurement of plant production/biomass and assessment of wetland functions and values	*Phragmites* biomass estimates at 4 transects in BCSA (Eight Day Swamp, Walden Swamp, Berry's Creek Marsh, Tollgate Marsh); three sample plots at each transect during mid-late August	Estimate of marsh landscape-level productivity within BCSA and compared with reference sites, survey of marsh functional parameters across BCSA and compared with reference sites

(1) Collected concurrent with Task 5A.
(2) Collected concurrent with Task 3E.
(3) Collected concurrent with Task 5C.
(4) Collected concurrent with Task 5E.
(5) Collected concurrent with Task 5F.

Table 3-7 Number of COPC Tissue Samples by Species and Segment

Study Segment	Length (m)	Number of Composite Samples by Species and Study Segment			
		Mummichog	White Perch	Blue Crab	Fiddler Crab
BCC	1,900	7	6 Whole Body/ 6 Fillet	6 Muscle Tissue/ 6 Carcass/ 3 Hepatopancreas	3
LBC	3,500	20	6 Whole Body/ 6 Fillet	6 Muscle Tissue/ 6 Carcass/ 3 Hepatopancreas	3
MBC	2,700	20	6 Whole Body/ 6 Fillet	6 Muscle Tissue/ 6 Carcass/ 3 Hepatopancreas	3
UBC	1,700	20	6 Whole Body/ 6 Fillet	6 Muscle Tissue/ 6 Carcass/ 3 Hepatopancreas	3

Notes: 67 locations sampled for mummichog; 24 for white perch and blue crab; 12 for fiddler crab.

Table 3-8 Phase 2/Task 6 - Reference Site Evaluation

Sub Task Number/Name	Rationale	Number/Location	Analytical Parameters
Task 6A			
Biota Sampling	Assess the presence of chemicals that may bioaccumulate/ biomagnify in reference areas through sampling across the range of conditions with co-located samples (surface water, sediment tissue).	21 locations; samples of mummichog, white perch (whole body and fillet composites at each location) and blue crab (muscle tissue and carcass) from 21 locations (hepatopancreas from 9 locations)	Total trace mercury Methyl mercury PCBs % Moisture Lipids
Task 6B			
Marsh Sediment Sampling	Assess the presence of chemicals that may bioaccumulate/ biomagnify in reference areas through sampling across the range of conditions with co-located samples (surface water, sediment tissue).	21 total marsh sediment samples (2 horizons) - for COPC analysis (0 to 15 cm) - 9 locations - Bellmans Creek - 3 locations - Mill Creek - 9 locations - Woodbridge River	COPC's (24 locations) Total mercury and methyl mercury Polychlorinated biphenyls Total Organic Carbon Sulfides and Sulfates Full List (18): Total mercury and methyl mercury TAL metals Polychlorinated biphenyls AVS/SEM Volatile Organic Compounds Semivolatile Organic Compounds Pesticides Biological oxygen demand Chemical oxygen demand Total Organic Carbon Grain Size Distribution Sulfides and Sulfates Cation Exchange Capacity % Moisture
	Assess mercury methylation/ demethylation	3 marsh sediment samples per reference site mercury methylation/demethylation study - 8 horizons, 2 cm (0 to 16 cm) - Total of 9 locations	Total mercury Methyl mercury pH/Redox (field) Sulfide/Sulfate TOC Salinity (in water) AVS/SEM

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Table 3-8 Phase 2/Task 6 - Reference Site Evaluation

Sub Task Number/Name	Rationale	Number/Location	Analytical Parameters
Task 6C			
Phragmites Sampling	Better understand the exchange of sediment and COPCs between the waterways and the marshes. Evaluate the potential exposure point concentrations in marsh invertebrate/insect habitats. Evaluate potential exposure point concentrations for mammals in the marsh system	3 sample locations from each of the following media (all co-located) from each reference area location (9 locations, 4 compartments) - *Phragmites* leaves (living) - Dead and decaying coarse material from the base of the plants - The detritus layer just above the root zone sediments - *Phragmites* roots	COPCs (mercury, methyl mercury, PCB's, TAL metals, TOC) Stable Isotopes (C, N, S) COPCs (no stable isotopes)
Task 6D			
Fish Community Survey	Characterize and compare fish communities.	3 segments - Bellmans/Woodridge Creek 1 segment - Mill Creek 4 trawling stations in each segment; 3 gill net stations in each segment; 20 minnow traps in each segment; 3 water quality stations in each segment; 7 segments sampled throughout system	Comparisons between segments of water quality parameters (temperature, dissolved oxygen, salinity) and fish community metrics (relative species abundance, richness, evenness, diversity)
Task 6E			
Food Web Study/Fish Dietary Analysis	Understand trophic relationships.	7 segments 3 Bellman's, 1 Mill Creek, 3 Woodbridge) 20 fish per species per segment targeted for visual gut content analysis: Mummichog, White Perch (juvenile and adult); dry mass analysis for one composite sample of each species in each segment (9 total)	Gut content enumeration and taxonomic identification; dry mass analysis of dominant taxa in diet
Food Web Study/Stable Isotope Study	Understand trophic relationships.	3 samples of each biota compartment from each reference site segment (7)	Stable Isotopes (^{13}C, ^{15}N, ^{34}S)
Task 6F			
Benthic Survey	Identify composition and diversity of benthic community.	3 sampling locations per segment in Bellman's Creek with two samples per location (one on exposed mudflat, one in thalweg in subtidal area) (18 samples)	Comparison between segments and with BCSA of benthic invertebrate community metrics (relative species abundance, richness, evenness, diversity)

Table 3-8 Phase 2/Task 6 - Reference Site Evaluation

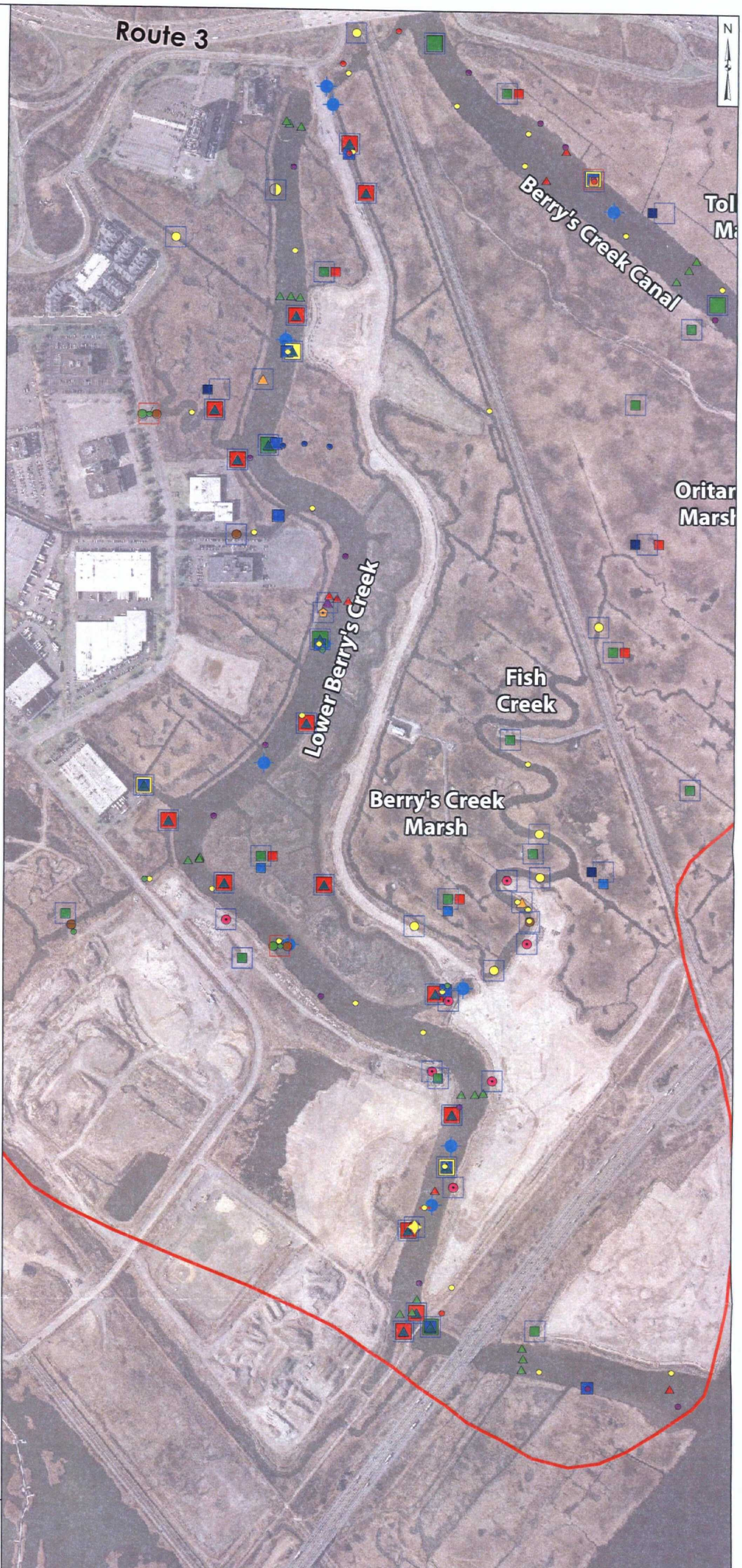
Sub Task Number/Name	Rationale	Number/Location	Analytical Parameters
Task 6G			
Survey of Marsh Invertebrate/Insect Community	Characterize and compare marsh invertebrate communities in space and time, evaluate collection methods.	3 marshes - Bellmans/Woodridge 1 marsh - Mill Creek 1 Light trap sample per marsh; 1 Malaise trap sample per marsh; 2 Vacuum samples per marsh	Comparison between marshes of invertebrate community metrics (relative species abundance, richness, evenness, diversity) and potential habitat niche contribution to uppr trophic levels
Task 6H			
Evaluation of Reference Site Marsh Production, Functions, and Values	Understand potential impact of COPCs on marshes using measurement of plant production/biomass and assessment of wetland functions and values	*Phragmites* biomass estimates at 3 transects across reference sites; three sample plots at each transect during mid-late August - 9 - Bellmans - 3 - Mill Creek - 9 - Woodbridge	Estimate of marsh landscape-level productivity within reference sites and compared with BCSA, survey of marsh functional parameters across reference sites and compared with BCSA

Sample Phase
Phase 2 Sample Co-located with Phase 1 Sample
Phase 2 Sample

Phase 2 Samples
Hydrodynamics
Laser In Situ Scatter and Transmissometry (LISST) Monitor
Acoustic Doppler Velocimeter (ADV) - Short Term
Acoustic Doppler Current Profiler (ADCP) - Short Term
Acoustic Doppler Current Profiler (ADCP) - Long Term
Acoustic Doppler Velocimeter (ADV) - Long Term
Dye Drop Location
High-Frequency ADV
Sedflume Coring Location
Upland Freshwater Input Location
Waterway Pool Transect Monitoring
Storm Surge Transect Monitoring
Surface Water
Manual Stormwater Sample
Manual Surface Water Sample
Waterway Autosampler (Routine and Storm)
Tributary Autosampler (Storm)
Marsh-Waterway COPC Exchange Sampler
Marsh Intertidal Pool Sample
COPC Fractionation
Sediment
Mummichog Correlation Sediment Sample
High Resolution Waterway Sediment Core (0-1 m)
Waterway Sediment Core (0-60 cm)
Waterway BAZ Sample
Marsh COPC Core (0-15 cm)
Marsh Methylation Study Core (0-16 cm)
Marsh Methylation Study/Organic Matter Fractionation (0-16 cm)
Deep Marsh COPC Core (0-50 cm)
Deep Marsh COPC/Geochronology Core (0-50 cm)
Phragmites/Marsh Sample
Biota
Mummichog Biota Sample (COPC)
Mummichog, White Perch, and Blue Crab Biota Sample (COPC)
Mummichog, White Perch, Blue Crab, and Fiddler Crab Biota Sample (COPC + Stable Isotopes)
Groundwater-Surface Water Interaction
Well Cluster
Single Well

Phase 1 Samples
Hydrodynamics
Mobile Hydrodynamic Monitoring Stations
Surface Water
Manual Surface Water Sample (Modified Quarterly Sample)
Manual Surface Water Sampling Location (Modified Quarterly Sampling) and Manual Stormwater Sampling Location
Sediment
General Biologically Active Zone (BAZ) Sample Location
General Biologically Active Zone (BAZ) Sample Location with Dioxin
Transect/Deep Core
BAZ Only
BAZ Only with Dioxin
Radiological/Constituents of Potential Concern Core
15cm to 30cm - Constituents of Potential Concern Core
Biota
Biota Sample
Marsh
Marsh Sample Location

200 100 0 200 Meters
800 400 0 800 Feet



Notes:

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2008 Aerial Photography provided by New Jersey Office of Information Technology (NJOIT), Office of Geographic Information Systems (OGIS), Trenton, NJ.

Location of Phase 1 and Phase 2 Sampling Programs in LBC

Phase 2 Work Plan Addendum
Berry's Creek Study Area
October 2010

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Figure 3-1

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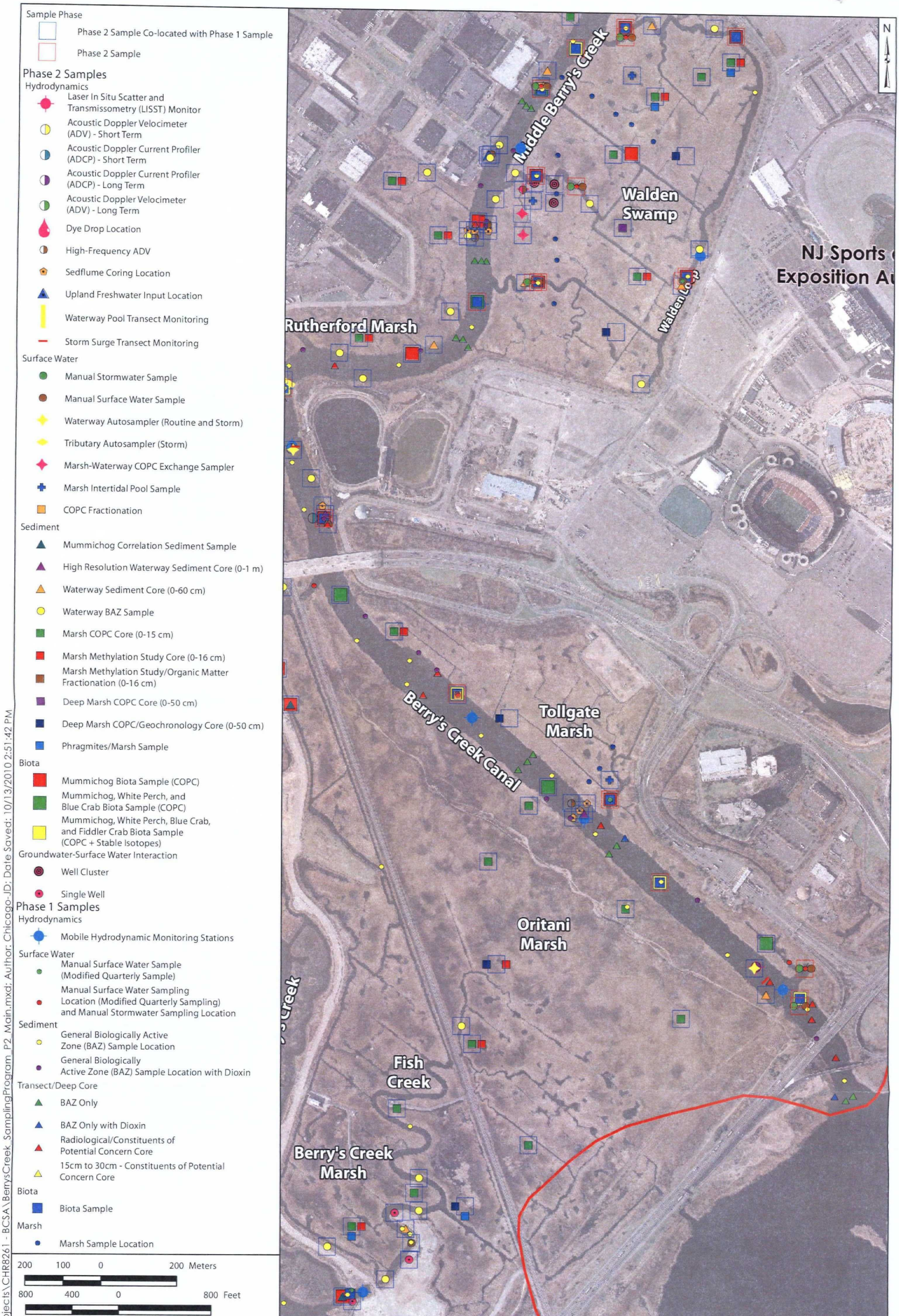

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Location of Phase 1 and Phase 2 Sampling Programs in BCC		
Phase 2 Work Plan Addendum Berry's Creek Study Area October 2010	Geosyntec consultants / integral	Figure **3-2**

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Sample Phase

- Phase 2 Sample Co-located with Phase 1 Sample
- Phase 2 Sample

Phase 2 Samples

Hydrodynamics
- Laser In Situ Scatter and Transmissometry (LISST) Monitor
- Acoustic Doppler Velocimeter (ADV) - Short Term
- Acoustic Doppler Current Profiler (ADCP) - Short Term
- Acoustic Doppler Current Profiler (ADCP) - Long Term
- Acoustic Doppler Velocimeter (ADV) - Long Term
- Dye Drop Location
- High-Frequency ADV
- Sedflume Coring Location
- Upland Freshwater Input Location
- Waterway Pool Transect Monitoring
- Storm Surge Transect Monitoring

Surface Water
- Manual Stormwater Sample
- Manual Surface Water Sample
- Waterway Autosampler (Routine and Storm)
- Tributary Autosampler (Storm)
- Marsh-Waterway COPC Exchange Sampler
- Marsh Intertidal Pool Sample
- COPC Fractionation

Sediment
- Mummichog Correlation Sediment Sample
- High Resolution Waterway Sediment Core (0-1 m)
- Waterway Sediment Core (0-60 cm)
- Waterway BAZ Sample
- Marsh COPC Core (0-15 cm)
- Marsh Methylation Study Core (0-16 cm)
- Marsh Methylation Study/Organic Matter Fractionation (0-16 cm)
- Deep Marsh COPC Core (0-50 cm)
- Deep Marsh COPC/Geochronology Core (0-50 cm)
- Phragmites/Marsh Sample

Biota
- Mummichog Biota Sample (COPC)
- Mummichog, White Perch, and Blue Crab Biota Sample (COPC)
- Mummichog, White Perch, Blue Crab, and Fiddler Crab Biota Sample (COPC + Stable Isotopes)

Groundwater-Surface Water Interaction
- Well Cluster
- Single Well

Phase 1 Samples

Hydrodynamics
- Mobile Hydrodynamic Monitoring Stations

Surface Water
- Manual Surface Water Sample (Modified Quarterly Sample)
- Manual Surface Water Sampling Location (Modified Quarterly Sampling) and Manual Stormwater Sampling Location

Sediment
- General Biologically Active Zone (BAZ) Sample Location
- General Biologically Active Zone (BAZ) Sample Location with Dioxin

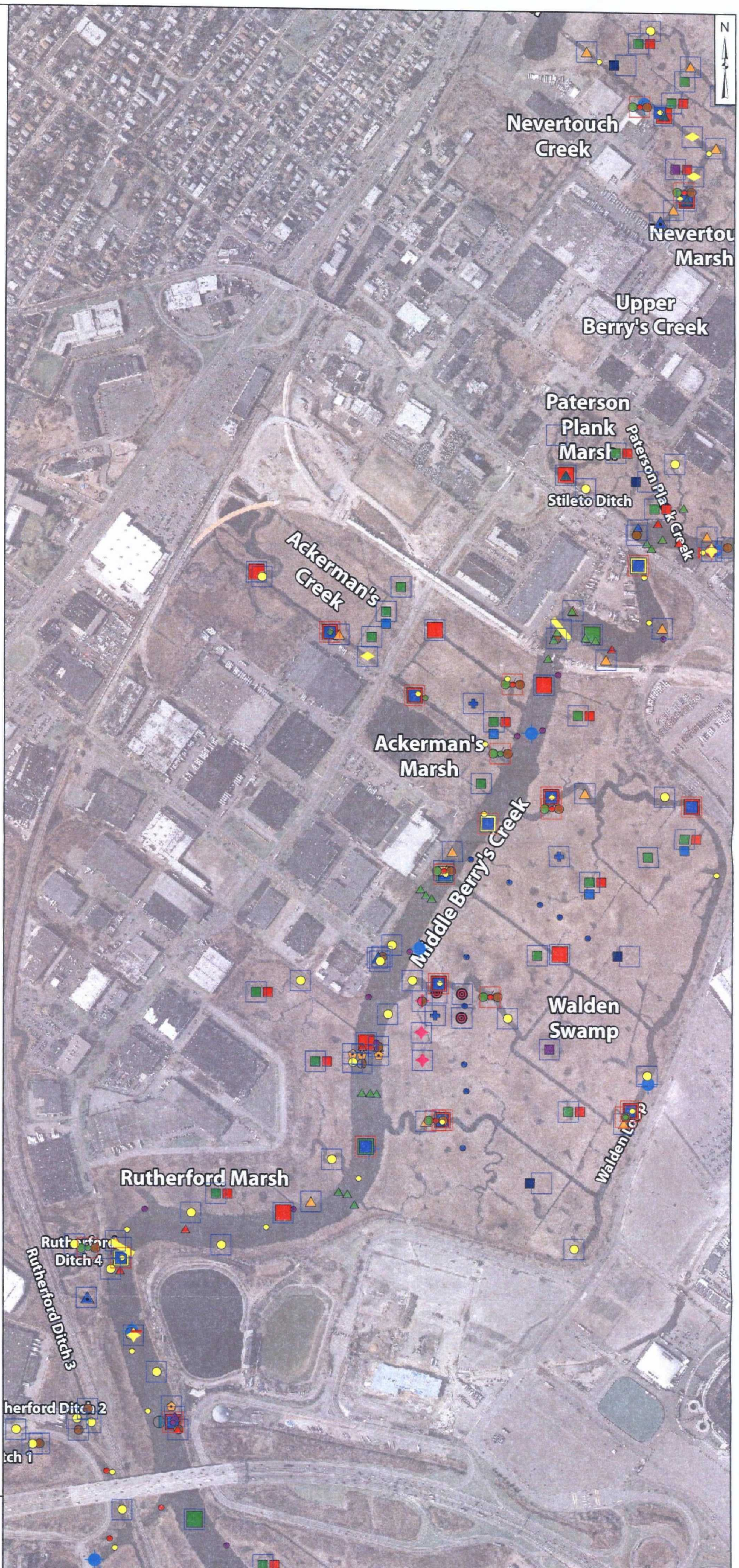
Transect/Deep Core
- BAZ Only
- BAZ Only with Dioxin
- Radiological/Constituents of Potential Concern Core
- 15cm to 30cm - Constituents of Potential Concern Core

Biota
- Biota Sample

Marsh
- Marsh Sample Location

200 100 0 200 Meters

800 400 0 800 Feet



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Location of Phase 1 and Phase 2 Sampling Programs in MBC

Phase 2 Work Plan Addendum
Berry's Creek Study Area
October 2010

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Figure 3-3

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Sample Phase

Phase 2 Sample Co-located with Phase 1 Sample

Phase 2 Sample

Phase 2 Samples

Hydrodynamics

- Laser In Situ Scatter and Transmissometry (LISST) Monitor
- Acoustic Doppler Velocimeter (ADV) - Short Term
- Acoustic Doppler Current Profiler (ADCP) - Short Term
- Acoustic Doppler Current Profiler (ADCP) - Long Term
- Acoustic Doppler Velocimeter (ADV) - Long Term
- Dye Drop Location
- High-Frequency ADV
- Sedflume Coring Location
- Upland Freshwater Input Location
- Waterway Pool Transect Monitoring
- Storm Surge Transect Monitoring

Surface Water

- Manual Stormwater Sample
- Manual Surface Water Sample
- Waterway Autosampler (Routine and Storm)
- Tributary Autosampler (Storm)
- Marsh-Waterway COPC Exchange Sampler
- Marsh Intertidal Pool Sample
- COPC Fractionation

Sediment

- Mummichog Correlation Sediment Sample
- High Resolution Waterway Sediment Core (0-1 m)
- Waterway Sediment Core (0-60 cm)
- Waterway BAZ Sample
- Marsh COPC Core (0-15 cm)
- Marsh Methylation Study Core (0-16 cm)
- Marsh Methylation Study/Organic Matter Fractionation (0-16 cm)
- Deep Marsh COPC Core (0-50 cm)
- Deep Marsh COPC/Geochronology Core (0-50 cm)
- Phragmites/Marsh Sample

Biota

- Mummichog Biota Sample (COPC)
- Mummichog, White Perch, and Blue Crab Biota Sample (COPC)
- Mummichog, White Perch, Blue Crab, and Fiddler Crab Biota Sample (COPC + Stable Isotopes)

Groundwater-Surface Water Interaction

- Well Cluster
- Single Well

Phase 1 Samples

Hydrodynamics

- Mobile Hydrodynamic Monitoring Stations

Surface Water

- Manual Surface Water Sample (Modified Quarterly Sample)
- Manual Surface Water Sampling Location (Modified Quarterly Sampling) and Manual Stormwater Sampling Location

Sediment

- General Biologically Active Zone (BAZ) Sample Location
- General Biologically Active Zone (BAZ) Sample Location with Dioxin

Transect/Deep Core

- BAZ Only
- BAZ Only with Dioxin
- Radiological/Constituents of Potential Concern Core
- 15cm to 30cm - Constituents of Potential Concern Core

Biota

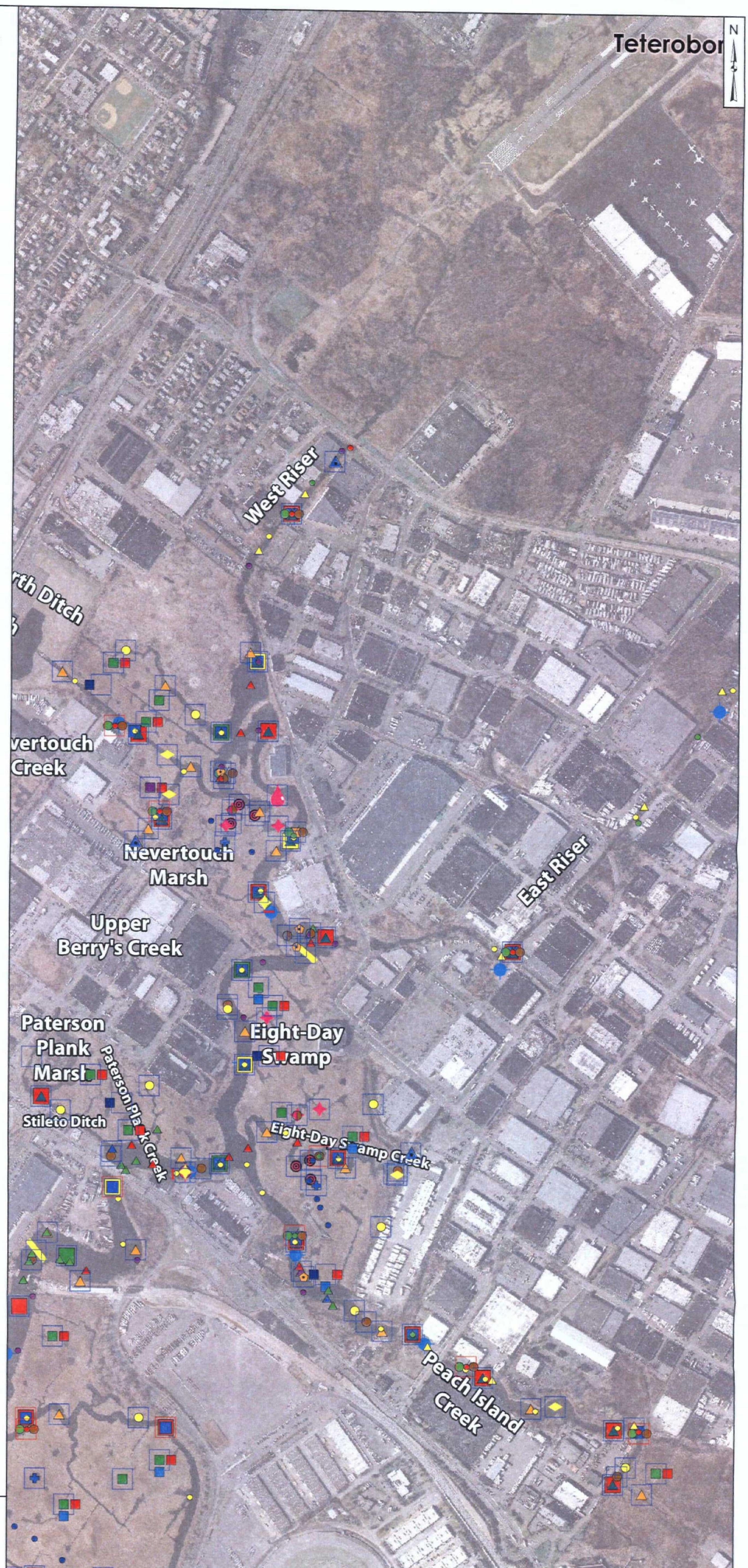
- Biota Sample

Marsh

- Marsh Sample Location

200 100 0 200 Meters

800 400 0 800 Feet



Notes:

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2008 Aerial Photography provided by New Jersey Office of Information Technology (NJOIT), Office of Geographic Information Systems (OGIS), Trenton, NJ.

Location of Phase 1 and Phase 2 Sampling Programs in UBC

Phase 2 Work Plan Addendum
Berry's Creek Study Area
October 2010

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Figure 3-4

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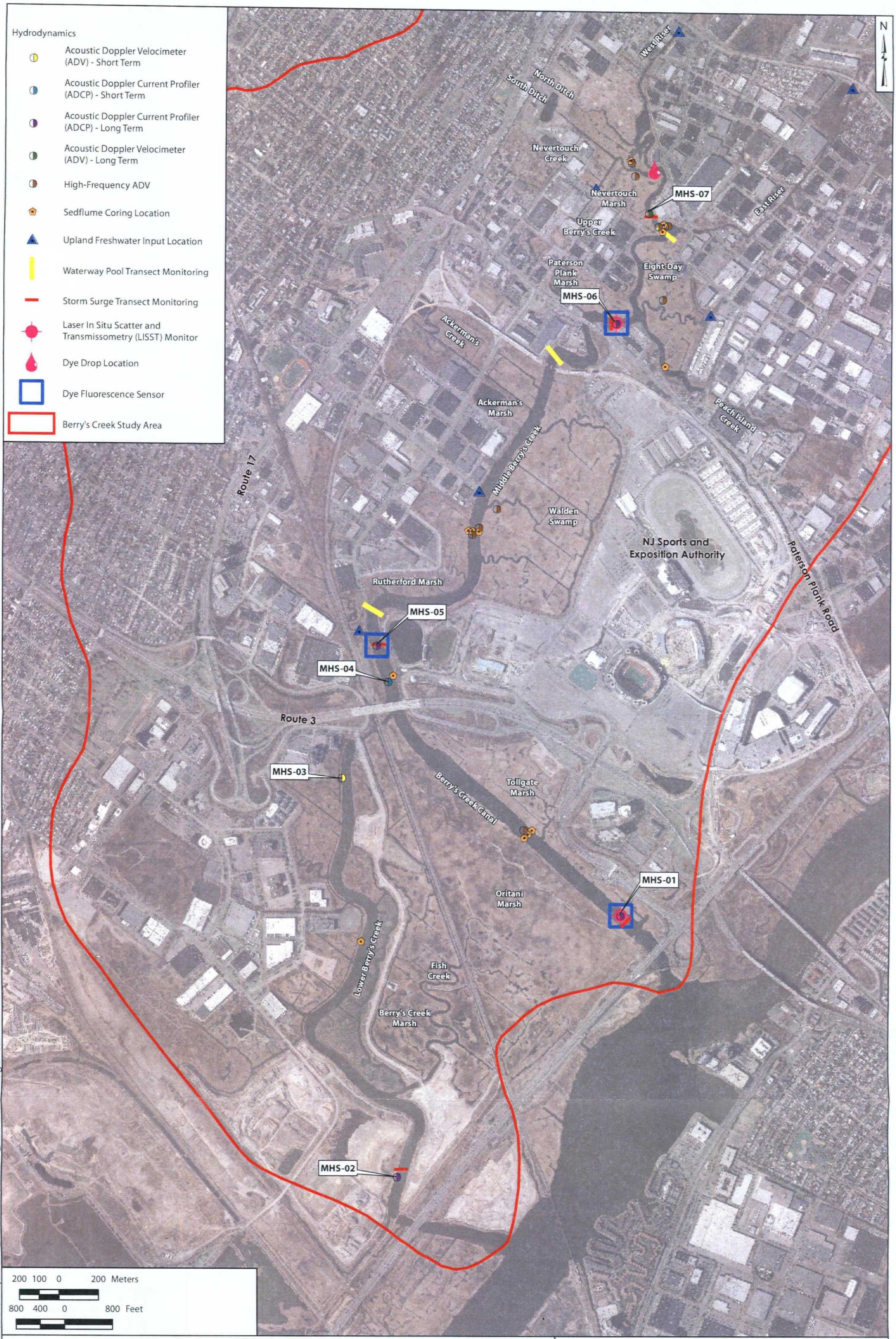

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Locations of Hydrodynamics Monitoring Stations in Berry's Creek Study Area

Phase 2 Work Plan Addendum Berry's Creek Study Area October 2010	Geosyntec consultants / integral	Figure 3-5

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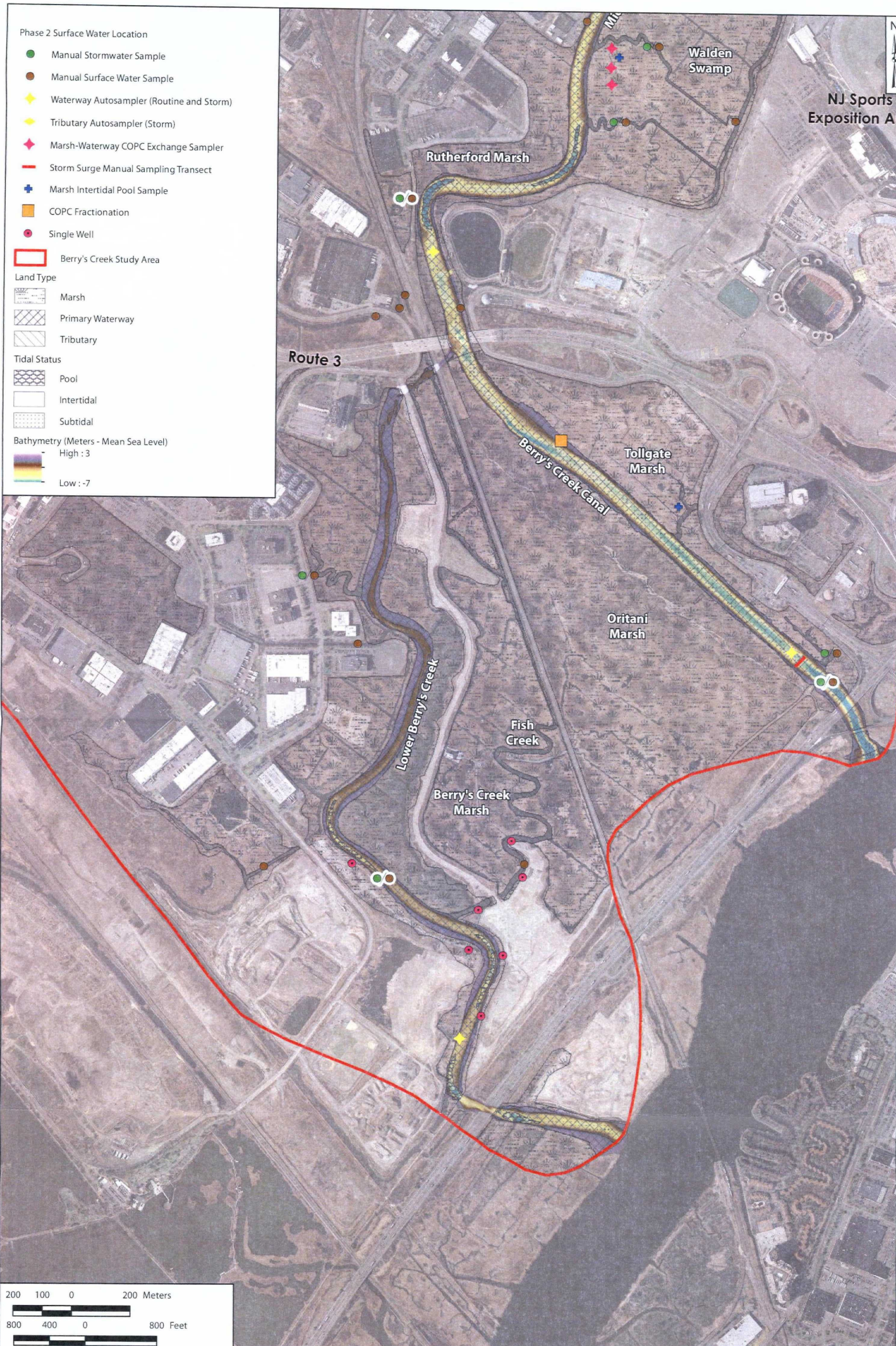

Notes:
For Phase 2 Sediment sample locations, symbols outlined in white indicate that the full analytical list will be run on all samples at that location whereas symbols outlined in black indicate that the full analytical list will be run on BAZ samples only at that location
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Phase 2 Surface Water Sampling Program Locations in LBC and BCC

Phase 2 Work Plan Addendum
Berry's Creek Study Area
October 2010

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Figure
3-6

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Phase 2 Surface Water Sampling Program Locations in MBC and UBC

Phase 2 Work Plan Addendum
Berry's Creek Study Area
October 2010

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Figure
3-7

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Phase 2 Sediment Sampling Program Locations in LBC and BCC

Phase 2 Work Plan Addendum
Berry's Creek Study Area
October 2010

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Figure 3-8

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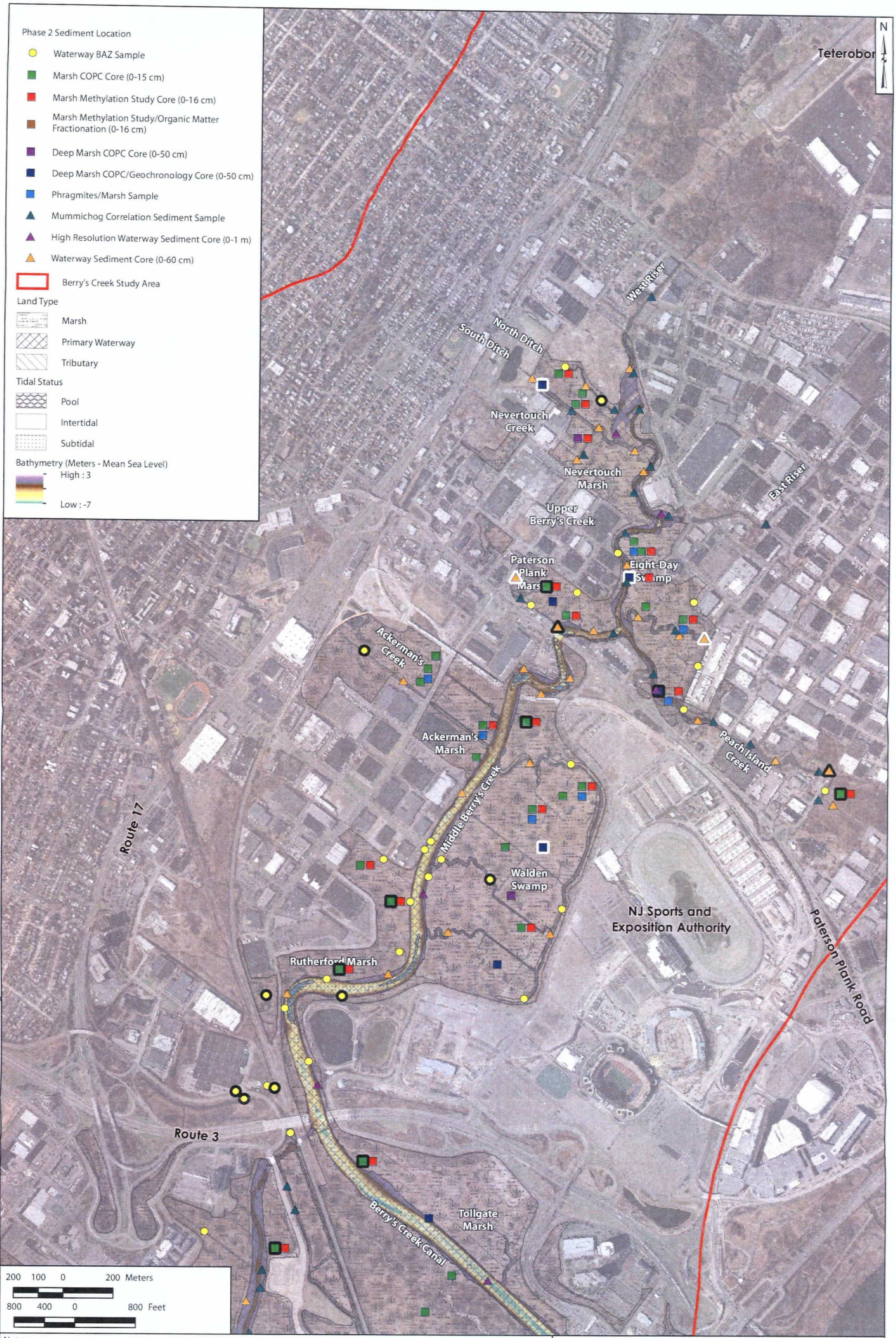

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Phase 2 Sediment Sampling Program Locations in MBC and UBC

Phase 2 Work Plan Addendum
Berry's Creek Study Area
October 2010

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Figure 3-9

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Phase 2 Marsh Well Locations in Berry's Creek Study Area

Phase 2 Work Plan Addendum Berry's Creek Study Area October 2010	Geosyntec consultants / integral	Figure 3-10

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Phase 2 Landfill Well Locations in Berry's Creek Study Area		
Phase 2 Work Plan Addendum Berry's Creek Study Area October 2010	Geosyntec consultants / integral	Figure 3-11

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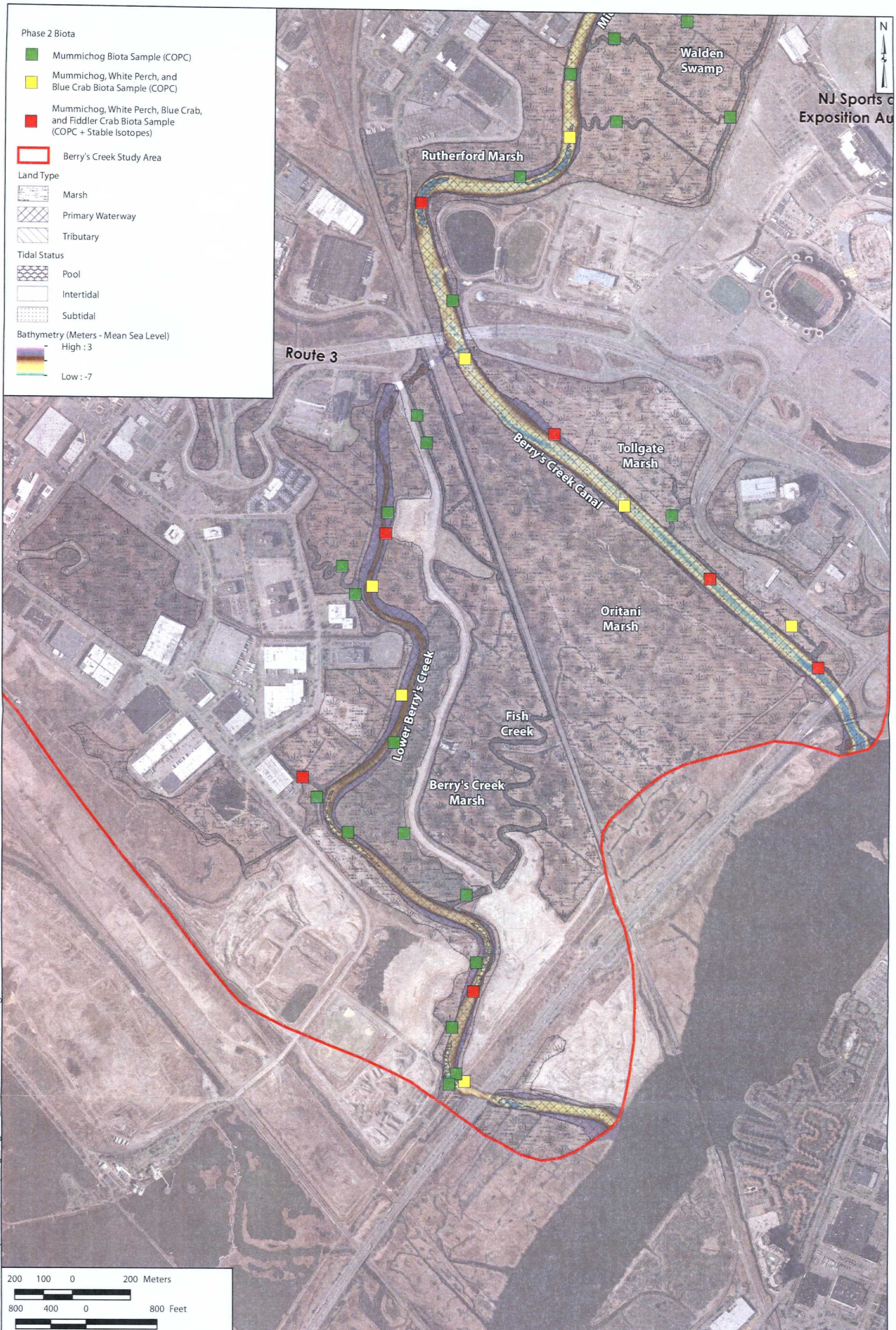

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Phase 2 Biota Sampling Program Locations in LBC and BCC

Phase 2 Work Plan Addendum Berry's Creek Study Area October 2010	Geosyntec consultants / integral	Figure 3-12

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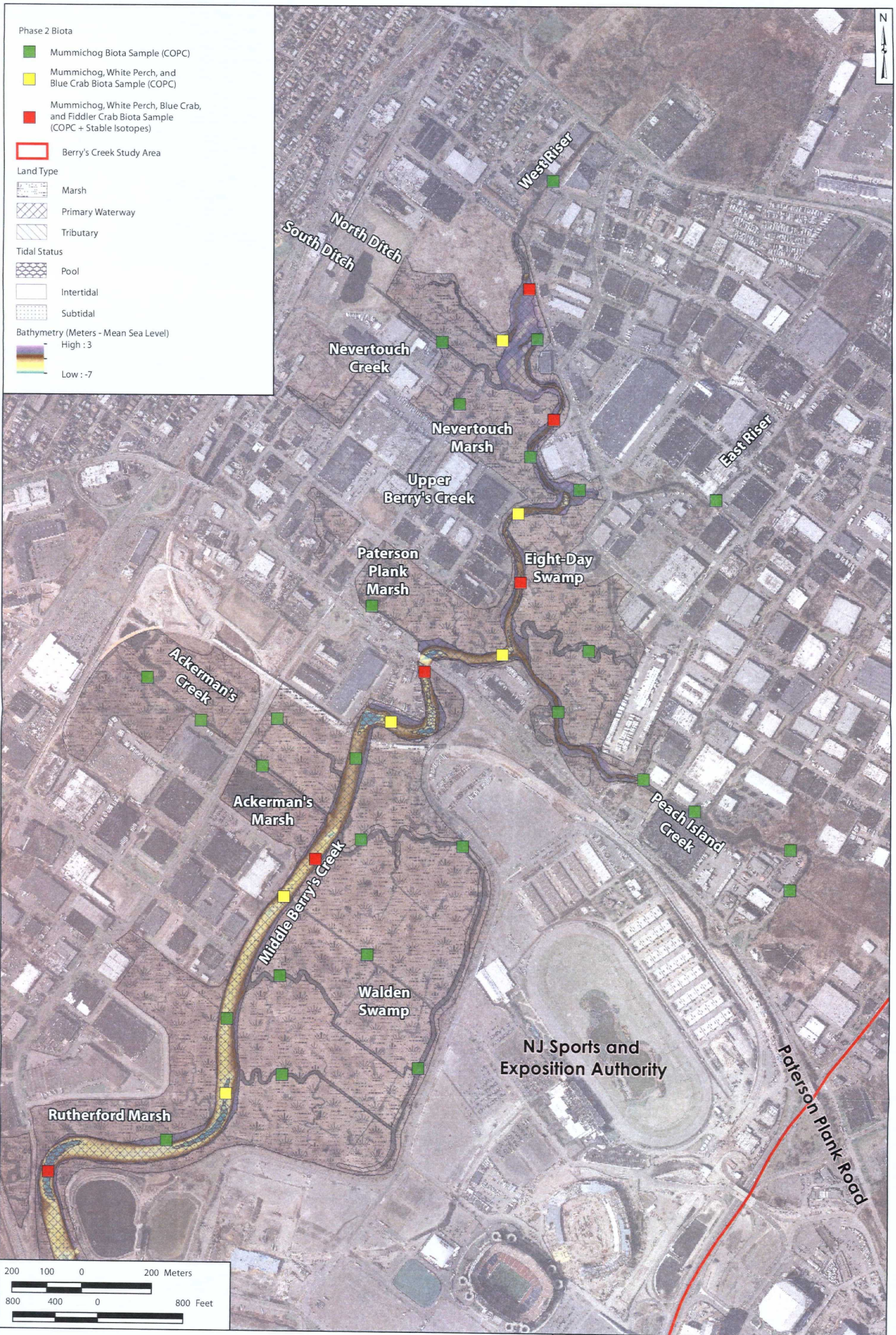

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Phase 2 Biota Sampling Program Locations in MBC and UBC

Phase 2 Work Plan Addendum
Berry's Creek Study Area
October 2010

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Figure 3-13

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Observer Name: ______________________________ **Date:** __________ **Time:** ________am/pm

Location Description: ______________________ **Latitude:** __________ **Longitude:** __________

Weather (circle one): Clear Overcast Rain **Group Size:** _____ (complete a line below for each individual)

Observations:

Obs	Approximate Age	Sex	Location	Activity	Individual Notes
1	___ Child (0-6) ___ Adolescent (>6-18) ___ Adult (>18) ___ Unknown	___ Male ___ Female ___ Unknown	___ Bridge ___ Road ___ (in) Creek ___ Creek bank ___ Marsh ___ Boat	___ Crabbing ___ Fishing ___ Swimming ___ Boating ___ Work ___ Other	
2	___ Child (0-6) ___ Adolescent (>6-18) ___ Adult (>18) ___ Unknown	___ Male ___ Female ___ Unknown	___ Bridge ___ Road ___ (in) Creek ___ Creek bank ___ Marsh ___ Boat	___ Crabbing ___ Fishing ___ Swimming ___ Boating ___ Work ___ Other	
3	___ Child (0-6) ___ Adolescent (>6-18) ___ Adult (>18) ___ Unknown	___ Male ___ Female ___ Unknown	___ Bridge ___ Road ___ (in) Creek ___ Creek bank ___ Marsh ___ Boat	___ Crabbing ___ Fishing ___ Swimming ___ Boating ___ Work ___ Other	
4	___ Child (0-6) ___ Adolescent (>6-18) ___ Adult (>18) ___ Unknown	___ Male ___ Female ___ Unknown	___ Bridge ___ Road ___ (in) Creek ___ Creek bank ___ Marsh ___ Boat	___ Crabbing ___ Fishing ___ Swimming ___ Boating ___ Work ___ Other	
5	___ Child (0-6) ___ Adolescent (>6-18) ___ Adult (>18) ___ Unknown	___ Male ___ Female ___ Unknown	___ Bridge ___ Road ___ (in) Creek ___ Creek bank ___ Marsh ___ Boat	___ Crabbing ___ Fishing ___ Swimming ___ Boating ___ Work ___ Other	
6	___ Child (0-6) ___ Adolescent (>6-18) ___ Adult (>18) ___ Unknown	___ Male ___ Female ___ Unknown	___ Bridge ___ Road ___ (in) Creek ___ Creek bank ___ Marsh ___ Boat	___ Crabbing ___ Fishing ___ Swimming ___ Boating ___ Work ___ Other	

Signs of Human Activity:
___ Crabbing Equipment
___ Fishing Equipment
___ Watercraft
___ Other

Additional Notes:

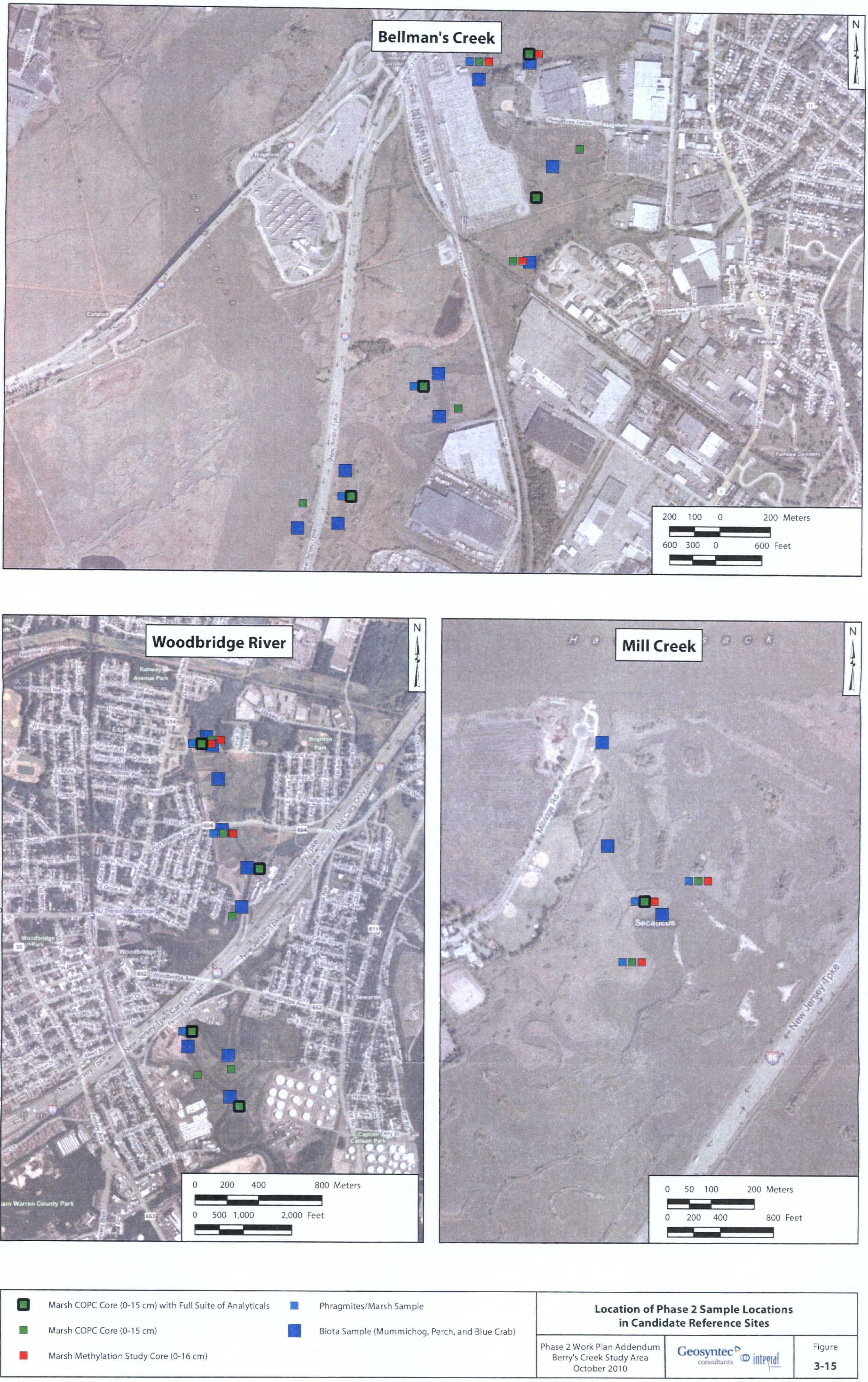
Notes:

Observations of Human Use in the Berry's Creek Study Area

Phase 2 Work Plan Addendum
Berry's Creek Study Area
October 2010

Figure 3-14

P:\prj1\CWP\CHR8261 - Berry's Creek Study Area RI-FS\5.0 Documents-Geosyntec\5.1 Project Plans\5.1.1 Work Plan\Draft 3.13.09\Figures\Figure 8-7. Human Use_pdj.ai[8.5 x 11 portrait



Location of Phase 2 Sample Locations in Candidate Reference Sites

Phase 2 Work Plan Addendum
Berry's Creek Study Area
October 2010

Geosyntec consultants | integral

Figure 3-15

H:\GISProjects\CHR8261 - BCSA\BerrysCreek_P2_Workplan_Candidate_ReferenceSites.mxd; Chicago - JD

Figure 7-1
Schedule

ID	Task Name	Duration	Start	Finish
1	Phase 2 RI/FS	0 days	Mon 6/21/10	Mon 6/21/10
2	EPA Approves Work Plan (Partial Approval)	1 day	Fri 7/16/10	Fri 7/16/10
3	EPA Approves Work Plan (Full Approval)	1 day	Mon 1/31/11	Mon 1/31/11
4	Field Mobilization	0.5 mons	Mon 7/19/10	Fri 7/30/10
5	Task 1 - Evaluation of Site Hydrology/Hydrodynamics/Sediment Transport (RI-P2-T1)	375 days	Mon 7/19/10	Fri 12/23/11
6	1A - Moored Station Hydrodynamic and Water Quality Monitoring Stations (RI-P2-T1A)	375 days	Mon 7/19/10	Fri 12/23/11
7	1B - Collection of Transect Data (RI-P2-T1B)	235 days	Mon 1/31/11	Fri 12/23/11
8	1C - Suspended Solids Characterization	333 days	Mon 9/13/10	Wed 12/21/11
17	1D - Dye Tracer Field Activities (RI-P2-T1D)	1 mon	Tue 4/5/11	Mon 5/2/11
18	1E - High Freq. Monitoring of Sed Bed Flow Vel. And SS in Waterways	235 days	Mon 1/31/11	Fri 12/23/11
19	1F - Monitoring of Upland Freshwater Inputs	235 days	Mon 1/31/11	Fri 12/23/11
20	1G - Sedflume	5 days	Wed 6/8/11	Tue 6/14/11
21	Task 2 - Surface Water Investigation (RI-P2-T2)	380 days	Mon 7/19/10	Fri 12/30/11
22	2A - Routine Monitoring	315 days	Mon 7/19/10	Fri 9/30/11
23	2A1 - Automated Sampling	106 days	Mon 7/19/10	Mon 12/13/10
27	2A2 - Manual Sampling	106 days	Mon 7/19/10	Mon 12/13/10
31	2A3 - Automated Storm Event Sampling (RI-P2-T2A03)	315 days	Mon 7/19/10	Fri 9/30/11
34	2A4 - Manual Storm Event Sampling (RI-P2-T2A04)	275 days	Mon 9/13/10	Fri 9/30/11
36	2B - Phase 2 Specific Monitoring (RI-P2-T2B)	380 days	Mon 7/19/10	Fri 12/30/11
37	2B1 - Marsh-Waterway COPC Exchange (RI-P2-T2B01)	106 days	Mon 7/19/10	Mon 12/13/10
42	2B2 - Marsh Intertidal Pool Sampling (RI-P2-T2B02)	106 days	Mon 7/19/10	Mon 12/13/10
46	2B3 - Particulate COPC Fractionation Methods Development (RI-P2-T2B03)	115 days	Mon 2/21/11	Fri 7/29/11
48	2B4 - Storm Surge Manual Surface Water Sampling (RI-P2-T2B04)	240 days	Mon 1/31/11	Fri 12/30/11
49	Task 3 - Sediment Investigation (RI-P2-T3)	204 days	Mon 8/9/10	Thu 5/19/11
50	3A - Low Res Waterway Sediment Core Sampling (RI-P2-T3A)	7 wks	Fri 4/1/11	Thu 5/19/11
51	3B - Supplementary BAZ Sediment Sampling (RI-P2-T3B)	32 days	Thu 8/12/10	Fri 9/24/10
52	3C - Sediment Surface Investigation for Correlation to Biota COPC Residues (RI-P2-T3C)	7 wks	Mon 8/9/10	Fri 9/24/10
53	3D - Marsh Sediment Sampling (RI-P2-T3D)	54 days	Tue 8/10/10	Fri 10/22/10
54	3E - Phragmites Sampling	30 days	Mon 8/16/10	Fri 9/24/10
55	3F - High Res WW Sediment	7 wks	Fri 4/1/11	Thu 5/19/11
56	Task 4 - Surface Water/Groundwater Interactions (RI-P2-T4)	106 days	Mon 7/19/10	Mon 12/13/10
57	4A - Marsh Interflow Characterization	101 days	Mon 7/26/10	Mon 12/13/10
58	Well Installation/Development/Slug Test	2 wks	Mon 7/26/10	Fri 8/6/10
59	Summer Sampling	11 days	Mon 9/6/10	Mon 9/20/10
60	Fall Sampling	11 days	Mon 11/29/10	Mon 12/13/10
61	4B - Focused Sampling of Groundwater Discharge	106 days	Mon 7/19/10	Mon 12/13/10
62	Well Installation/Development/Slug Test	2 wks	Mon 7/19/10	Fri 7/30/10
63	Summer Sampling	11 days	Mon 9/6/10	Mon 9/20/10
64	Fall Sampling	11 days	Mon 11/29/10	Mon 12/13/10

Figure 7-1
Schedule

ID	Task Name	Duration	Start	Finish
65	Task 5 - Biota Investigation and Human Activity Assessment (RI-P2-T5)	247 days	Mon 6/21/10	Tue 5/31/11
66	5A - COPC Residues in the BCSA Food Web	5 wks	Mon 8/2/10	Fri 9/3/10
67	5B - Human Use Survey (RI-P2-T5B)	227 days	Mon 7/19/10	Tue 5/31/11
68	5C - Fish Community Survey (RI-P2-T5C)	14 days	Mon 7/26/10	Thu 8/12/10
69	5D - Food Web Study (RI-P2-T5D)	32 days	Mon 7/19/10	Tue 8/31/10
72	5E - Benthic Survey (RI-P2-T5E)	7 days	Mon 8/23/10	Tue 8/31/10
73	5F - Qualitative Survey of Invertebrate/Insect Community (RI-P2-T5F)	35 days	Mon 7/19/10	Fri 9/3/10
76	5G - Evaluation of BCSA Marsh Production, Functions, and Values	35 days	Mon 7/12/10	Fri 8/27/10
80	5H - Marsh PFV	1 day	Mon 6/21/10	Mon 6/21/10
81	Task 6 - Reference Site Evaluation (RI-P2-T6)	50 days	Mon 8/2/10	Fri 10/8/10
82	6A - Biota Sampling	5 wks	Mon 8/16/10	Fri 9/17/10
83	6B - Marsh Sediment Sampling	15 days	Mon 9/20/10	Fri 10/8/10
84	6C - Phragmites Sampling	15 days	Mon 9/20/10	Fri 10/8/10
85	6D - Fish Community Survey	9 days	Mon 8/2/10	Thu 8/12/10
86	6E - Food Web Study	22 days	Mon 8/2/10	Tue 8/31/10
89	6F - Benthic Survey	7 days	Mon 8/23/10	Tue 8/31/10
90	6G - Qualitative Survey of Invertebrate/Insect Community	10 days	Mon 9/6/10	Fri 9/17/10
92	6H - Evaluation of Marsh Production, Functions, and Values in Reference Sites	10 days	Mon 9/6/10	Fri 9/17/10
96	Task 7 - Air Sampling	209 days	Tue 3/1/11	Fri 12/16/11
97	7A - Atmospheric Deposition Assessment	120 days	Tue 3/1/11	Mon 8/15/11
98	7B - Air Monitoring	209 days	Tue 3/1/11	Fri 12/16/11
99	Task 8 - Regional Background Data Review	110 days	Mon 2/14/11	Fri 7/15/11
100	Task 9 - Data Management/Validation	365 days	Mon 7/26/10	Fri 12/16/11
101	Task 10 - Modeling (Data Collection and Analysis)	355 days	Mon 8/9/10	Fri 12/16/11
102	Task 11 - Draft Phase 2 Report/Phase 3 Work Plan Addendum	271 days	Tue 3/1/11	Tue 3/13/12
103	11A - Prepare Draft Report	242 days	Tue 3/1/11	Wed 2/1/12
104	11B - Phase 3 WorkPlan Addendum	82 days	Mon 11/21/11	Tue 3/13/12
105	Task 12 - Phase 2 Findings and Phase 3 Workplan Presentation	1 day	Mon 2/13/12	Mon 2/13/12
106	Task 13 - Revised Phase 2 Report and Phase 3 Addendum	80 days	Tue 2/14/12	Mon 6/4/12
107	Task 14 - IRM Letter Report	1 day	Thu 3/15/12	Thu 3/15/12
108	Task 15 - EEA Technical Memorandum	1 day	Mon 3/12/12	Mon 3/12/12
109	Task 16 - Pathways Analysis Report	1 day	Mon 3/12/12	Mon 3/12/12
110	Task 17 - Development and Screening of Remedial Alternatives	151 days	Mon 12/19/11	Mon 7/16/12
111	Task 17A - Development	120 days	Mon 12/19/11	Fri 6/1/12
112	Task 17B - Tech Memo	30 days	Tue 6/5/12	Mon 7/16/12
113	Task 17C - Presentation to USEPA	30 days	Tue 6/5/12	Mon 7/16/12
114	Task 18 - Baseline Monitoring Program	239 days	Fri 3/4/11	Wed 2/1/12
115	Task 18a - Submit Draft Baseline Monitoring Program Workplan	1 day	Fri 3/4/11	Fri 3/4/11
116	Task 18b - Conduct Year 1 Baseline Monitoring Program	130 days	Mon 5/16/11	Fri 11/11/11
117	Task 18c - Reporting	88 days	Mon 10/3/11	Wed 2/1/12